JOURNAL

OF THE

ASSOCIATION OF ENGINEERING SOCIETIES.

Boston. St. Louis. Chicago. Cleveland.

TRANSACTIONS

Of the Boston Society of Civil Engineers, the Engineer's Club of St. Louis the Western Society of Engineers, and the Civil Engineers' Club of Cleveland.

VOLUME I.

November, 1881, to October, 1882.

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ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. I. NOVEMBER, 1881. No. 1.

This Association, as a body, is not responsible for the subject matter of any society, or for statements or opinions of any of its members.

THE ASSOCIATION OF ENGINEERING SOCIETIES.

Nearly eighteen months have elapsed since the project of the joint publication of the proceedings of various engineering societies was proposed.

To the Civil Engineers' Club of Cleveland, at that time probably the youngest association of engineers in the country, belongs the credit of originating the scheme.

About the 1st of May, 1880, a plan for securing a joint publication of proceedings of sundry engineering societies was brought to the attention of the officers of many, if not all, of the engineering societies of the country, by Mr. A. M. Wellington, of Cleveland, in the shape of proposed articles of association. These articles were finally submitted to the Boston Society of Civil Engineers, the Western Society of Engineers, the Engineers' Club of St. Louis, and the Civil Engineers' Club of Cleveland, all of which looked so favorably upon the general features of the proposed plan that committees were soon after appointed by each of the associations named to correspond with similar committees and officers of kindred societies, for the purpose of more fully perfecting the plan.

The committee for the Boston Society consisted of Henry Manley, Frederick Brooks, and S. E. Tinkham; for the Western Society, of L. P. Morehouse, Charles MacRitchie, and Benezette Williams; for the St. Louis Club, of Prof. Charles A. Smith, and for the Cleveland Club, of Charles Paine, A. M. Wellington, and M. E. Rawson.

After an extended correspondence, a meeting was held in Chicago on December 4, 1880, for the purpose of deciding finally upon articles of association.

The following extract from the minutes of the meeting shows the

progress that had been made up to that time, as well as the constitution of the meeting:

The meeting was called to order at 10.45 A. M. Present, Messrs. Benezette Williams and L. P. Morehouse, of the Committee on Joint Publication of the Western Society of Engineers: John W. Weston, Member W. Society, Eng. (by invitation): M. E. Rawson and A. M. Wellington, of the Committee of the Civil Engineers' Club of Cleveland; Prof. Chas. A. Smith, of the Committee of the Engineers' Club of St. Louis. The Committee of the Boston Society of Civil Engineers was represented by letter.

On motion, Mr. Benezette Williams was chosen Chairman, and Mr. A. M. Wellington Secretary.

On motion, the Boston Society of Civil Engineers, having expressed a disposition to join in the movement and appointed a committee, and having also expressed their views in detail on the proposed forms of agreement through their special committee. was considered to be represented and entitled to vote in case of disagreement on points specifically touched upon by their letters.

It was ascertained on inquiry that the St. Louis and Cleveland committees had plenary powers to act for their clubs. The committees of the Chicago and Boston organizations had only power to report and recommend.

The Secretary read a communication from the Secretary of the Engineers' Club of Philadelphia, stating that their club had concluded contracts for another year, and, having already an independent publication of their own, were not at present prepared to act in the matter; also a communication to a similar effect from the Engineers' Society of Western Pennsylvania. The Engineers' Club of the Gulf States and several minor organizations had not been heard from.

After a full discussion and comparison of the various plans proposed, the articles of association, printed elsewhere in this issue of the JOURNAL, were agreed upon.

These articles were subsequently submitted to the several societies by their committees, which societies voted to enter the proposed Association. The assent of the Boston Society of Engineers was secured January 19, 1881; of the Engineers' Club of St. Louis, January 5, 1881; of the Civil Engineers' Club of Cleveland, January 8, 1881, and of the Western Society of Engineers, April 5, 1881.

By this action of the societies, and the appointment of the Board of Managers, the Association of Engineering Societies was formed. Mr. A. M. Wellington was appointed Manager by the Civil Engineers' Club of Cleveland, and on his resignation, to fill a professional engagement in Mexico, Mr. M. E. Rawson was appointed to the vacancy.

The organization of the Board of Managers was finally perfected at a meeting of the Board held in Cleveland, O., June 11, 1881.

The Association has been called into being by no narrow spirit. Many of its promoters believe that local engineering societies should be established and fostered in every center of population where the engineering profession is sufficiently strong to support one; thus bringing each member within the easiest possible reach of his society. They also believe that these local societies should be brought into affiliation by some association with a wider sphere of action, by means of which common purposes may be executed, and through which their energies may be stimulated to high professional aims.

While many have been actuated by this broad spirit, the co-operation of

these widely-separated societies has been, perhaps, mainly secured through a desire to effect an interchange of professional papers. To this desire the first number of the JOURNAL of the Association may be said to owe its origin,

May we not hope that this act of co-operation is merely the initial stage in the development of an organization from which more than the interchange of papers will be realized, and for which we may reasonably predict a great future?

We surely indulge the belief that the articles of association were not only begotten in a generous spirit, and are not only founded upon correct principles, but that they possess sufficient vitality and adaptability to permit growth in any direction which experience may indicate as desirable; that by wise counsel and the cultivation of a professional esprit de corps, an organization will ultimately be evolved from this beginning which will perform a work not now being done by any association in the land; a work beneficial to the participating societies as societies, and to every engineer who desires a better tone and higher standing for the engineering profession.

In saying this we are not unmindful of the imperfections which are known to exist in the plan of organization, and of the probable existence of still other defects which are not now so apparent.

We do not, however, believe these defects to be fatal. We think that any tendency endangering the prosperity or usefulness of the Association can be counteracted by the adoption of measures which come fully within the scope of action prescribed by the articles under which the Association exists.

On behalf of the participating societies, the Board of Managers ask for the Association and its publication the earnest support of its friends, and the candid consideration of those to whom the wisdom of its creation has not as yet been made manifest.

They also appeal to kindred societies for their co-operation, hoping thereby to establish a medium for the interchange of professional literature which will be enduring: and to create an Association which, by a unity of professional interests, will be perpetual in its benefits.

For the purpose of securing the benefits of closer union and the advancement of mutual interests, the Engineering Societies and Clubs hereunto subscribing have agreed to the following

ARTICLES OF ASSOCIATION.

ARTICLE I.

Name and Object.

The name of this Association shall be "The Association of Engineering Societies." Its primary object shall be to secure a joint publication of the papers and transactions of the participating societies.

ARTICLE II.

Organization.

SEC. 1. The affairs of the Association shall be conducted by a Board of Managers, under such rules and by-laws as they may determine, subject to the specific conditions of these articles. The Board shall consist of one representative from each society of one hundred members or less, with one additional representative

for each additional one hundred members, or fraction thereof over fifty. The members of the Board shall be appointed as each society shall decide, and shall hold office until their successors are chosen.

SEC. 2. The officers of the Board shall be a chairman and secretary, the latter of whom may or may not be himself a member of the Board.

ARTICLE III.

Duties of Officers.

SEC. 1. The Chairman, in addition to his ordinary duties shall countersign all bills and vouchers before payment, and present an annual report of the transactions of the Board ; which report, together with a synopsis of the other general transactions of the board of interest to members, shall be published in the Journal of the Association.

SEC. 2. The Secretary shall be the active business agent of the Board and shall be appointed and removed at its pleasure. He shall receive a compensation for his services, to be fixed from time to time by a two-thirds vote. He shall receive and take care of all manuscript copy and prepare it for the press, and attend to the forwarding of proof-sheets and the proper printing and mailing of the publications. He shall have power, with the approval of any one member of the Board, to return manuscript to the author for correction if in bad condition, illegible, or otherwise conspicuously deficient or unfit for publication. He shall certify to the correctness of all bills before transmitting them to the chairman for counter-signature. He shall receive all fees and moneys paid to the Association, and hold the same under such rules as the Board shall prescribe.

ARTICLE IV.

Publications.

SEC. 1. Each society shall decide for itself what papers and transactions of its own it desires to have published, and shall forward the same to the Secretary.

SEC. 2. Each society shall notify the Secretary of the minimum number of copies of the joint publications which it desires to receive, and shall furnish a mailing-list for the same from time to time. Copies ordered by any society may be used as it shall see fit. Payments by each society shall in general be in proportion to the number of copies ordered, subject to such modification of the same as the Board of Managers may decide, by a two-thirds vote, to be more equitable. Assessments shall be quarterly in advance, or otherwise, as directed by the Board.

SEC. 3. The publications of the Association shall be open to public subscription and sale, and advertisements of an appropriate character shall be received, under regulations to be fixed by the Board.

SEC. 4. The Board shall have authority to print with the joint publication such abstracts and translations from scientific and professional journals and society transactions as may be deemed of general interest and value.

ARTICLE V.

Conditions of Participation.

SEC. 1. Any Society of Engineers may become a member of this Association by a majority vote of the Board of Managers, upon payment to the Secretary of an entrance fee of fifty cents for each active member, and certifying that these Articles of Association have been duly accepted by it. Other technical organizations may be admitted by a two-thirds vote of the Board, and payment and subscription as above.

SEC. 2. Any society may withdraw from this Association at the end of any fiscal year by giving three months' notice of such intention, and shall then be entitled to its fair proportion of any surplus in the treasury, or be responsible for its fair proportion of any deficit.

SEC. 3. Any society may, at the pleasure of the Board, be excluded from this

Association for non-payment of dues, after thirty days' notice from the Secretary that such payment is due.

ARTICLE VI.

Amendments.

These articles may be amended by a majority vote of the Board of Managers, and subsequent approval by two-thirds of the participating societies.

ARTICLE VII.

Time of Going into Effect.

These articles shall go into effect whenever they shall have been ratified by three societies, and members of the Board of Managers appointed. The Board shall then proceed to organize, and the entrance fee of fifty cents per member shall then become payable.

PROCEEDINGS.

A meeting of the Board of Managers of the Association of Engineering Societies was held at the City Hall, Cleveland, O., June 11, 1881.

The meeting was called to order by the President, Benezette Williams, at 2.30 P. M.

Present: Mr. Benezette Williams, from the Western Society of Engineers, Chicago; Mr S. E. Tinkham, of the Boston Society of Civil Engineers, and M. E. Rawson, of the Civil Engineers' Club of Cleveland, the remaining member, Prof. Charles A. Smith, of the Engineers' Club of St. Louis, by telegraph announced his inability to be present, but hoped the matter might be pushed forward.

On motion, the previous action taken, by which Mr. Benezette Williams was elected President of the Board of Managers by letter ballot, was confirmed; and Mr. M. E. Rawson was elected Secretary pro tem.

The question as to the manner in which the joint publication of the Society proceedings should be issued was then taken up, the President submitting three propositions from the *American Engineer* and a fourth made up of offers from other responsible parties.

The first proposition from the *American Engineer*, provides for publishing all proceedings and papers in the columns of that journal, each of the members of the various societies to be furnished a copy of the same, and at the end of the year with a bound volume of the Proceedings, for which the societies are to pay the sum of $3 for each number.

The second provided for furnishing 500 copies of a monthly publication, including mailing, postage, and the work of a secretary, and a copy of the *American Engineer* to every member of the four societies for one year, for the sum of $2,032.

The third included the same as the second, except the work of a secretary, and the furnishing of a copy of the *American Engineer* to each member—cost $1,972.

The fourth scheme for a monthly publication was made up from propositions from various responsible parties, and provided for the same sized edition, and included work of a secretary, mailing, etc.—cost $1,989.58.

These various proposals were discussed at length, but owing to the fact that a proposition had been asked for upon a different basis, to which no answer had been received, it was decided to hold the matter open awaiting such answer.

The question of publishing the proceedings of the societies in a separate pamphlet, or in the columns of a journal, was then considered, and a motion was unani-

mously adopted favoring an independent monthly publication, embracing in each issue the proceedings and papers of each society.

On motion, it was decided that the matter of each society should be placed separately in the pamphlet, under the proper heading. The positions to be arranged in the order of the date of organization.

A form of title page was adopted and subsequently modified by action of the Board.

The question as to the time of the issue of the first number of the publication was left to be decided by correspondence.

The following was on motion adopted as one of the by-laws of the Board :

"Questions may be decided without a meeting of the Board, by correspondence. Motions shall be made and seconded and then forwarded to the President and by him communicated to each member of the Board, to be voted upon by letter ballot."

On motion the President was instructed to prepare a form of ballot to be used when voting by letter ballot.

On motion a scale of prices for advertisements was adopted.

Upon the question as to the nature and extent of the matter which each society should present for publication, no formal action was taken.

On motion the Board adjourned to meet at the call of the President.

M. E. Rawson, Secretary pro tem.

Since the Cleveland meeting, the Board has completed its organization by the election of H. G. Prout secretary, and has arranged to have the work of publication carried on under his charge at stipulate l rates.

BOSTON SOCIETY OF CIVIL ENGINEERS.

ORGANIZED 1848.

TRANSACTIONS.

[This Society is not responsible as a body for the statements and opinions advanced in any of its publications.]

BOSTON SOCIETY OF CIVIL ENGINEERS.

An informal meeting of gentlemen engaged principally in civil engineering was held April 26, 1848, at the United States Hotel in Boston, Mass., to consider the expediency of forming a society for social intercourse and professional improvement. This meeting did not formally organize, but those present engaged in a general conversation concerning the proposed society. Several subsequent meetings were held at short intervals, at which papers were read and a constitution framed.

The first regular meeting of the Boston Society of Civil Engineers was held July 3, 1848, at the rooms of the Boston Water Commissioners. At this meeting the following officers were elected: President, James F. Baldwin; Vice-President, George M. Dexter; Secretary, John H. Blake; Treasurer, William P. Parrott; Directors, Samuel Ashburner, Joseph Bennett, James Laurie, Samuel Nott, and William S. Whitwell. In addition to these officers, the following gentlemen were present at this or some of the preliminary meetings: U. A. Boyden, G. R. Baldwin, E. S. Chesbrough, F. Darracott, J. B. Francis, H. S. McKean, T. E. Sickels and T. S. Williams.

In answer to a petition from the Society, the Legislature passed an act, which was approved by the Governor April 24, 1851, incorporating George M. Dexter, Simeon Borden, William P. Parrott, their associates and successors, by the name of "The Boston Society of Civil Engineers, for the purpose of Promoting Science and Instruction in the Department of Civil Engineering." This act was accepted by the Society February 9, 1852. The membership then numbered 27, the average attendance at the meetings being about 13.

Previous to January 3, 1853, the Society had its room at No. 14 Joy's Building, but after this date it met at the rooms of the New England Association of Railroad Superintendents, No. 11½ Tremont Row, where, by mutual agreement, the two societies used the rooms in common, with a common library.

The Society continued in a prosperous condition, holding regula me e

ings, which were generally well attended, until the spring of 1855; after this time very few meetings were attended by a quorum, and consequently no business could be transacted.

A meeting was held September 13, 1861, at which Messrs. Waldo Higginson, and Samuel Ashburner were appointed a committee to take charge of the assets of the Society. This committee deposited the greater part of the books of the Society in the library of the Boston Athenæum, where they remained for about twelve years.

No further meetings of the Society were held until April 27, 1874, when a meeting was held at the office of Mr. Ernest W. Bowditch. At this meeting Mr. James B. Francis was elected President and Samuel Nott, Secretary, and a number of gentlemen who were members of a society of engineers in Boston, organized May 30, 1873, and which had unwittingly taken the name of the former society, were proposed for membership in the Boston Society of Civil Engineers. These gentlemen were elected as members of the Society June 5, 1874.

Since its reorganization the Society has had a very prosperous existence, monthly meetings have been held at which many interesting and valuable papers have been read and discussed. Beginning with the September, 1879, meeting, these papers, together with a brief record of each meeting, have been printed and distributed to the members. The membership has gradually increased, until now it numbers 99; of these 89 are active, 8 honorary and 2 corresponding members. Of those who took part in the organization of the Society, more than 33 years ago, 6 still maintain their connection with it. The present government of the Society is: President, Thomas Doane: Vice-President, Edward S. Philbrick; Secretary, S. Everett Tinkham; Treasurer, Henry Manley; Librarian, Frederick Brooks.

A FEW EXPERIMENTS ON PERCOLATION OF WATER THROUGH SAND.

By A. Fteley, Member of the Society.

[Read September 21, 1881.]

These experiments were made in 1876, to determine the percolating capacity of certain stratum of sand in which a portion of the foundation of a dam was to be established. The bed of sand was of such a depth, borings having failed to detect the presence of any coarser material 70 feet from the surfice, that it was out of the question to extend the foundation to a hard stratum, as the head of water behind the dam was not to exceed 25 feet. The problem to be solved consisted, consequently, in determining the depth to which the structure was to extend in order to reduce the velocity of the underground current to such a small figure as would preclude the possibility of displacement of the sandy particles.

The sand was gritty, of a reddish yellow color, with grains of a generally uniform bulk, averaging the size of a small pin's head.

The apparatus used consisted of a three-inch uncoated iron pipe, which was to contain the sand to be experimented upon. It was stopped at the bottom with a perforated cap with a sufficient number of openings to admit of the free flow of all the water that might percolate through the sand. On the cap rested an inch and a half of gravel to prevent the sand from washing through. It is obvious that the water does not percolate at the circumference of the pipe in the same condition as it does through the mass of sand. It is believed, however, that the absence of coating on the interior surface of the pipe, and the roughness of that surface is sufficient reason to admit that the general conditions of the flow were not disturbed to such an extent as to impair the fairness of the general results.

The cast-iron pipe was connected by a flexible rubber hose with a stand-pipe 1½ inches in diameter, so arranged as to admit of various heads of water. The heads of water used during the experiments were generally 27, 19, 16 and 8 feet above the top of the cast-iron pipe containing the sand.

Every time the sand was introduced into the pipe it was put in in small quantities and thoroughly rammed.

Seven Inches of Sand.—The first series of experiments was made with seven inches of sand only.

Experiments 1, 2, 3 and 4 are not recorded, as the head was not kept constant and the indications are not considered reliable.

The results of experiment No. 5 are given in full as they show a remarkable variation.

The head on the sand surface was 20 feet.

Hours and minutes.	Head.	Gallons in 24 hours, per square foot.
1.33 to 1.38	20 ft.	2,655
1.38 " 1.43	"	2,202
1.43 " 1.48	"	1,870
1.48 " 1.53	"	1,762
1.53 " 1.56	"	1,497
1.58 " 2.04	"	1,339
2.04 " 2.08	"	1,262
2.08 " 2.13	"	1,141
2.13 " 2.18	"	1,101
2.18 " 2.23	"	1,101
2.23 " 2.28	"	1,006
2.28 " 2.33	"	935
2.33 " 2.38	"	935
2.38 " 2.45	"	881

At the commencement of the experiment the sandpipe was empty, and it is probable that the rush of water, when it was let on, stirred up the sand, which was afterwards gradually compacted by the water passing through it.

Experiment No. 6.—Head increased to 31 feet by pouring water slowly; the experiment lasted 1 hour and five minutes. During the first five minutes the flow was 5,681 gallons per square foot in 24 hours; then 3,038, 3,091, 1,652, etc., in successive periods of five minutes until it came down by regular steps to 870 at the end.

Experiment No. 7.—The head was reduced to 20 feet, and the percolation varied in 24 minutes, from 385 to 352 gallons per 24 hours and per square foot.

Experiment No. 8.—Head reduced to 12 feet, and percolation varying in 12 minutes from 211 to 156 gallons.

Experiment No. 9.—Head increased again to 23 feet, and percolation, during fifteen minutes, varying from 396 to 374 gallons, very nearly equal to what it was in experiment No. 7, made under very similar conditions.

At the end of this experiment the sand pipe was disconnected, and it was found that the height of sand had diminished from 7 to $6\frac{3}{4}$ inches, or $3\frac{1}{2}$ per cent.*

Twelve and Three-quarter inches Head.—More sand was then rammed in until the thickness was $12\frac{3}{4}$ inches, and the full head was left on it a whole night before any records were made.

It was then found (experiment No. 10) that during 50 minutes the percolation had varied from 132 to 143 gallons (per square foot and per 24 hours); head, $30\frac{1}{2}$ feet.

Experiment No. 11.—One hour: 84 to 88 gallons; head, $22\frac{1}{2}$ feet.

Experiment No. 12.—One hour; 66 to 66 gallons; head, $19\frac{1}{2}$ feet.

Experiment No. 13.—One hour; 33 to 33 gallons: head, $10\frac{1}{2}$ feet.

Two Feet of Sand.—Experiment No. 14, made with two feet of sand, extended from 4.25 P.M of June 28 to 1.58 P.M. of June 30. During that time the rate of percolation was taken forty times. From 4.25 P.M. on the 28th to 7.10 A.M. on the 29th, under varying heads, the rate of percolation varied from 3,171 to 2,220 gallons.

Head 29.7 feet, from 7.10 A.M. to 12.51 P.M. (5 hours and 41 minutes) the rate of percolation varied from 3,009 to 1,358 gallons.

From 12.51 P.M. to 6.21 P.M. (5 hours and 30 minutes) 1,358 to 442 gallons, with a sudden and unexplained variation in the otherwise regular rate of decrease of the percolation at about 3 P.M.

From 7.01 A.M. to 1.58 P.M. on June 30 (6 hours 57 minutes) 405 to 292 gallons.

Experiment No. 14 is illustrated by one of the diagrams.

Experiment 15.—Head reduced to 21.7 feet: percolation, during 23 minutes, reduced from 183 to 165 gallons.

Experiment 16.—Head reduced to 18.7 feet; percolation, during 13 minutes, from 110 to 176 gallons, an unexplained increase.

Experiment 17.—Head 10.7 feet only, percolation during four successive periods of five minutes, 39, 110, 77, 99 gallons; an especially irregular showing.

Experiment No. 18.—Full head again; percolation for one hour from 100 to 72 gallons.

Three Feet of Sand.—Experiment No. 19, with three feet of sand, covered a much longer time, extending from July 3, 9 A. M., to July 18, M. The head of water was 28 feet. The operation is fully illustrated by one of the diagrams. It shows especially that the percolation increased con-

*One of the diagrams shows the results of experiments No. 5 and 6, and the corresponding rate of percolation as the head increases.

siderably by leaving the pipe empty a short time, and that it increased enormously from the rate of 26 gallons to that of 1,541 by merely rapping the sand-pipe smartly three or four times with a wooden billet. This result indicates the influence of slight perturbations of the sandy particles on the rate of percolation, and illustrates the danger of such operations as pile-driving in the vicinity of sand banks holding water. The writer remembers the failure of a canal bank which had successfully stood the test of years, owing, probably, to some extensive pile-driving which was taking place at the time several hundred feet away from the location of the break.

The water used during the experiments was taken from a deep well and was practically free from silt. At the outlet of the pipe it was invariably found free from sand.

Although the results presented above show some marked irregularities, they indicate, with very few exceptions, a constant decrease in the percolating capacity of the sand, and from the slow rate of decrease shown by the diagram illustrating experiment No. 19 it may be inferred that, in the course of time, the rate of percolation would become uniform, as it is found in nature when water flows through natural banks of porous materials under a constant head.

It is obvious that many irregularities must have been produced by the disturbance of the sand when water was poured on it, but even after making sufficient allowance for the imperfection of the apparatus the fact remains that a condition of perfect rest, for a certain length of time, is necessary to secure a uniform rate of percolation. In this connection it may be noticed by a reference to the diagram of experiment No. 19 that after the disturbance produced by striking the pipe, all other conditions remaining the same, the rate of percolation after six days was 95 gallons per square foot and per 24 hours, while it was only about 40 gallons six days after the beginning of the experiment.

These experiments may give some useful indications in regard to the management of artificial filter-beds, such as are extensively used in England, and on a smaller scale in this country, although the clogging of the surfaces by silt introduces an entirely new element in the operation.

It is obvious that the filtering capacity of sand beds, such as are constructed for artificial filtration, varies constantly, owing to the periodical disturbance of the surface, which must be removed when it is covered with silt, and to the frequent changes in the consumption of the communities which draw their supply from such reservoirs. This variation of the rate of filtration has a detrimental effect on the quality of the water filtered, and it is generally recognized that it is essential for a well-regulated filtering scheme to include a clear water reservoir of sufficient capacity to meet all the irregularities of the consumption; such a reservoir must be independent from the small tank usually connected with the filter-beds to regulate the head of water on their sand surface.

It is generally admitted that the rate of percolation through sand filters must be slow and uniform, and that the quality of the water filtered is dependant upon the perfect regularity of all the operations. This low velocity, the uniformity of fineness in the sand, and even the distance of the collecting drains from the surface, all work together to

produce that regularity of action over the entire filter-bed upon which its perfection depends.

If the sand is left too long a time without cleaning, it is apt to become irregularly compacted, and the water opens for itself some isolated channels, through which it flows with greater velocity, to the great detriment of its quality. One of the greatest advantages of the coarser material which is generally placed under the same beds is to prevent that concentration of flow.

For filtering water in large bodies, sand composed of grains from one-third of a millimeter to one millimeter in diameter is preferable, and it is better in proportion as the grains are more uniform in size. When the filtering sand contains such a large quantity of very fine particles that they cannot be eliminated by washing, it must be considered bad, as it soon forms, under the water pressure, into a compact mass through which filtration can not take place.

When filtration is conducted under proper conditions, all, or nearly all, the matters held in suspension can be eliminated, and it is found that bodies considerably smaller than the intermediate spaces of the sand grains and which can be detected only by a powerful microscope, are successfully retained.

The velocity with which water filters through sand is one of the principal elements of a successful operation, and as that velocity depends upon the head under which the water is made to flow, special attention must be given to the arrangement of the filter-beds. Authorities vary about the proper velocity to be adopted, probably on account of the various circumstances of each case, such as the ground available, the requirements of the supply, etc., etc., and also because each water requires its own peculiar velocity.

J. P. Kirkwood ("Filtration of River Waters") says that the rate should not exceed 8.8 inches per hour (132 gallons per square foot and per 24 hours) when the water is clean, nor get below 3.2 inches per hour (48 gallons per square foot and per 24 hours) when it becomes obstructed by the deposit; but, he adds, "these appear to be extremes, rather to be avoided than copied." He recommends, "as a fair exponent of the best English practice" a rate of 6 inches, equivalent to 90 gallons per square foot and per 24 hours.

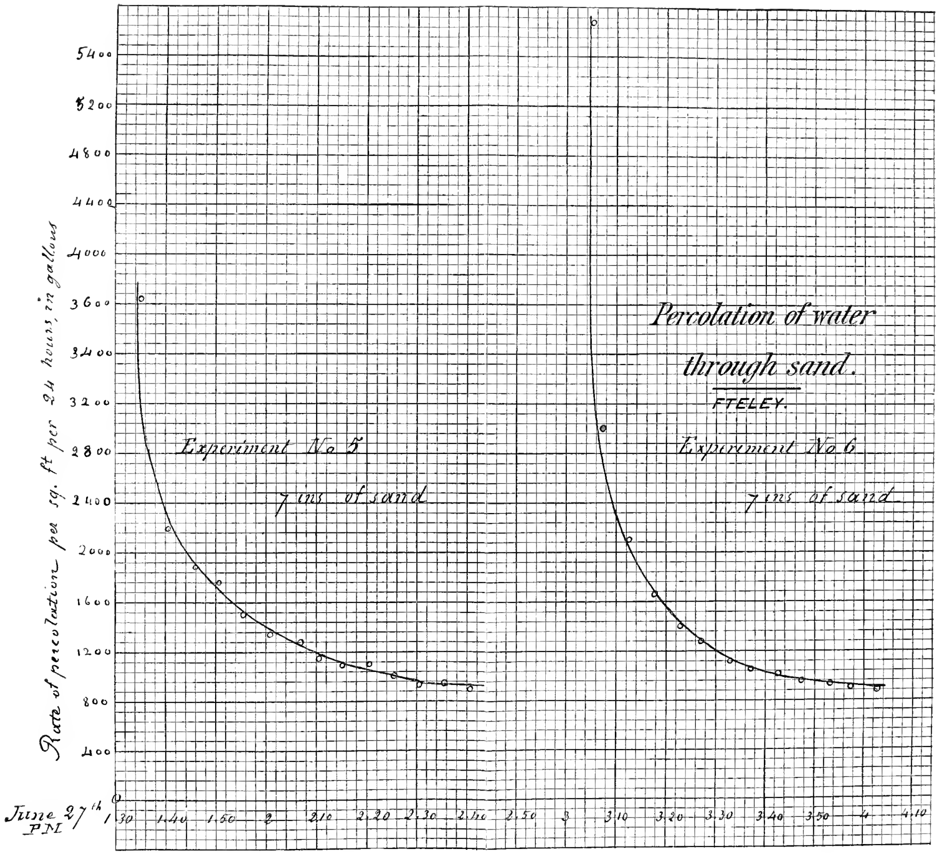
The proper filtering velocity of the Elbe water is estimated by a com-

RATE OF FILTRATION ADOPTED BY LONDON WATER COMMISSIONERS.

	Rate of Percolation per hour.	Gallons per square foot per 24 hours.
Lambeth Co.	10.7 inches.	160
Chelsea Co.	6.4 "	96
New River Co.	4.5 "	67.5
Southwalk and Vauxhall	3 "	45
Grand Junction	3 "	45
West Middlesex	2.7 "	40.5
East London	2.5 "	37.5

petent authority at 2.9 inches (43.5 gallons per square foot and per 24 hours).

The velocity of the water through the filter beds at Poughkeepsie for



Percolation of water through sand.
FTELEY.
Experiment No 5
7 ins of sand
Experiment No 6
7 ins of sand
Rate of percolation per sq. ft per 24 hours, in gallons
5400
5200
4800
4400
4000
3600
3400
3200
2800
2400
2000
1600
1200
800
400
0
June 27th PM
1.30
1.40
1.50
2
2.10
2.20
2.30
2.40
2.50
3
3.10
3.20
3.30
3.40
3.50
4
4.10

the year 1878 was 10.2 inches per hour, corresponding to 156 gallons per square foot and per day. I find that the rate of filtration as adopted by the London Water Commissioners is as shown in the table on p. 12.

It must be said, however, that the degree of turbidity of the water obtained from the filter-beds of the various companies varies considerably.*

From the data at hand it seems impossible to determine in a general manner the velocity to be adopted for filtering water through sand; it depends upon the nature of the water to be filtered, upon the nature of the sand which can be found within reach, upon the thickness of the bed of sand and upon other local conditions.

In special cases, the rate of percolation may vary very much from the figures given. Some experiments made in 1879, to find if a process of filtration could be successfully adopted when the water contains large quantities of algæ, showed that while the operation is possible, the surfaces of the filter-beds should be very much larger than usual, or the cleaning of the surfaces should be more frequent than it would otherwise be. In one instance, after one week, the filtering capacity of the filter, although it was worked under a greater head than it would be advisable to adopt in practice, was reduced to 17 gallons per square foot and per 24 hours, and after the surface had been allowed to dry, it was so much clogged up by the vegetable deposit that it was as hard as if it had been slightly frozen over.

No filtering works of great importance exist in this country but, it is obvious that the outlay necessary to build such works in connection with the water supply of a large city would be very large. The writer had occasion to make an estimate of the cost of filtering the water of Mystic Lake on the basis of a consumption of ten million gallons per day, and it was found that the cost of the plant, with the advantage of having all the filtering material on the ground, would amount to nearly half a million of dollars; the cost of yearly maintenance, including pumping, was eliminated at thirty thousand dollars. The area of the filter-beds was calculated for the rate of fifty gallons per square foot per twenty-four hours.

The rates of percolation mentioned above apply only in case of artificial filter-beds, and it is obvious that if the water to be treated is distributed over natural strata, the conditions in which the filtration takes place are entirely changed, but, in either case, the process of filtration cannot rid the water of the polluting matters which are held otherwise than in suspension. Although it is held by good authority that an appreciable proportion of the organic matter contained in solution can be eliminated by filtration through sand, the greater part of the polluting matters remain, and must contaminate the streams into which the filtered water finds its way ultimately.

DISCUSSION.

Mr. L. F. Rice:—Might not the action noticed, be by reason of the

* See report of Professor W. Ripley Nichols on the Filtration of Potable Water. New York, 1879: D. Van Nostrand, publisher.

water introduced reducing the weight or pressure of the upper particles of sand upon those lower down; the grains being agitated or shaken by the inflowing water—floated, as it were—so as to temporarily enlarge the interstices between the grains and thus give ready passage to the water? As soon as this initial disturbance ceased, the grains of sand would, by their gravity, settle down and find new beds, into which they would adjust themselves with more nicety and compactness than could possibly be done by ramming while dry. The percolation would then be reduced and the obstruction to flow would become more complete as the process of subsidence continued.

Mr. A. Fteley:—There must be a certain amount of disturbance caused among the particles of sand when water is first put in contact with them, but this disturbance cannot extend very far below the surface. The objection, however, was anticipated, and an experiment was made during which 10 lbs. of common shot was put on the surface of the sand in order to prevent any disturbance of the sand particles. The results were of the same general character as those obtained when the surface of the sand was left exposed to the action of the water.

Prof. Wm. Watson:—With regard to the purification of sewage by filtering through sand, I would like to call the attention of the Society to the experiments lately made at Gennevilliers by M. Schloesing, who has shown that sewage, or in general, waters charged with organic matters or ammoniacal salts, are oxidized by their passage through a soil sufficiently well aired and containing some trace of limestone. Sewage, always containing quite a large proportion of lime (0.400 k. to a cubic meter at Paris), is oxidized even by passing through an absolutely silicous soil such as quartz sand calcined to a red heat.

This oxidation is the result of a nitrogenous fermentation due to minute organisms analagous to the *micoderma aceti* and others, of which the functions have been so well defined by M. Pasteur.

These organisms, decomposing by their own life the organic or ammoniacal matters and fixing the oxygen, give rise to nitric acid, which combining with the lime of the soil or of the sewage, forms nitrates, *i. e.*, absolutely inoffensive mineral matters, which are found in theoretically pure filtered water.

Messrs. Schloesing and Muntz have isolated these organisms; they have seen them under the form of brilliant points; they have proved their efficacy by passing sewage through long tubes filled with calcined sand, or glass beads, and shown that after a short time what issued from the tubes was filtered water deprived of every trace of organic matter.

In order to demonstrate that these weie animals, the following experiment was made:

Chloroform vapor was introduced into the tubes, this anæsthetic paralyzed all the organisms working as ferments: the sewage was no longer oxidized in its passage through the tubes; a thorough washing was requisite to obtain a new oxidation by the development of new organisms. Thus the soil is an absolutely perfect instrument for purification.

Numerous analyses of the underground waters of Gennevilliers have shown the quantity of organic matter to be very slight, and often less

than that found in water used for drinking purposes. (0.00016 k. per cubic meter against 0.00021 k. in the Vanne, and 0.00024 k. in the Dhuis acqueducts supplying the City of Paris.)

Again, there were delivered to M. Marie-Davy, Director of the Montsouris Observatory, four basins 10 m. by 8.50 m., filled from 1.80 m. to 2 m. deep with earth from the plain of Gennevilliers: drain pipes were placed at the bottom, and the amount of sewage spread upon each basin accurately measured. The amount of water which filtered through was collected and also measured; vegetables, such as beets, corn, etc., were planted on the surface and the crop weighed with care when gathered. An exact account of the sewage water introduced, of the effluent water, and of that absorbed and evaporated by the plants was thus obtained. The purification was shown to be perfect from a chemical point of view, giving only 6 grammes of organic matter out of 2,262 grammes introduced. M. Marie-Davy, and his associate, M. Miguel, have, nevertheless, given an absolutely new demonstration of the purity of waters purified by the soil.

They have examined them by the microscope: they have counted the *microbes* or living motes which are to be found in a cubic centimeter of this water. Now, a centimeter of rain water contains 35 *microbes*, the Vanne acqueduct water 62, the Seine river water 1,200, and the sewage water 20,000 *microbes*. The water of these under-drains at Gennevilliers contains only from 13 to 24 *microbes*. Hence, the water flowing under the Gennevilliers plain filtered from the sewage distributed thereupon, is thus shown to be purer than the purest water from natural sources attainable in France.

But the most interesting result, obtained by M. Marie-Davy, is the following: Of 24,000 cubic meters of sewage per hectare distributed during six months, only 1,600 passed through 1.80 m. of depth, so that in a general way M. Marie-Davy concludes from his experiments that in distributing upon the soil from 5,000 to 6,000 cubic meters per month, *i. e.*, from 60,000 to 72,000 cubic meters per annum, only $\frac{1}{30}$ of the water will pass through to the underground waters. Vegetation comes in as a powerful upward drainage. The soil has transformed the sewage it has received, has oxidized it, and made of it an excellent liquid manure.

The plants absorb the useful elements of this manure, and return to the atmosphere by evaporation almost the totality of the liquid which has carried these same elements. Thus purification and agricultural utilization complete each other.

If a city seeks, before all else, the purification of its sewage, it will force the doses and depend upon the soil to convert all the organic matter into harmless materials, which cannot be wholly utilized by the vegetation.

When agricultural utilization comes in, the doses may be lessened so as to avoid all loss of the fertilizing materials. The plants spread over a space more or less extended will not suffer an atom of purified but fertile water to escape.

Not only purification but restitution itself will then be complete.

PROCEEDINGS.

SEPTEMBER 21, 1881 :—A regular meeting of the Society was held, President Doane in the chair, and fifteen members present.

The record of the last meeting was read and approved.

The resignation of Mr. Frederick Brooks of the office of Librarian, and also of his membership of the committees on Metric System and Class-List of Engineering Books in the Public Library, was received and accepted.

The Treasurer was authorized to pay upon the certificate of the Secretary and approval of the President, the assessments levied upon the Society from time to time by the Board of Managers of the Association of Engineering Societies, to defray the expenses of the joint publication of proceedings.

Mr. George G. Saville was elected a member of the Society, and Mr. William S. Barbour proposed for membership by Messrs. Geo. A. Kimball, and Thomas Doane.

Mr. A. Fteley read a paper on "Percolation of Water Through Sand," which was discussed by Messrs. Watson, Rice, and Whittaker.

President Doane read two communications, one describing a "Flying Ferry on the Snake River in Washington Territory," and the other a "Water-Lifter at Boisé City, Idaho."

[*Adjourned.*] S. E. TINKHAM, Secretary.

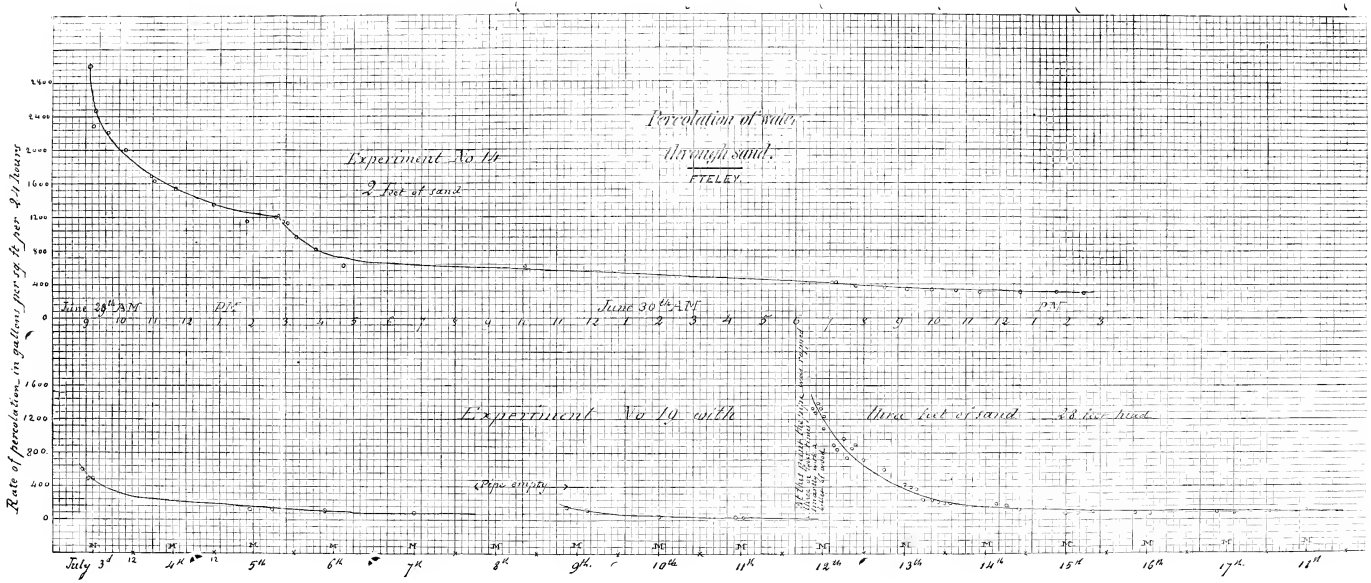
OCTOBER 19, 1881 :—A regular meeting of the Society was held, Mr. A. H French in the chair, and nine members present.

The reading of the record of the last meeting was dispensed with.

Mr. William S. Barbour was elected a member of the Society, and Prof. George L. Vose proposed for membership by Messrs. John E. Cheney and Thomas W. Davis.

Mr. George R. Hardy read some notes on the relation of civil engineers to the railroads of the country, and contrasted the different policy pursued by the Eastern roads with that of the main trunk lines of the West. He also briefly discussed the improvements made in rail sections, and other details of maintenance of way.

[*Adjourned.*] S. E. TINKHAM, Secretary.



Percolation of water through sand.
FTELEY.
Experiment No 14
2 Feet of sand
Experiment No 19 with three feet of sand 28 feet head
Rate of percolation in gallons per sq. ft. per 24 hours
2800
2400
2000
1600
1200
800
400
0
June 29th AM
PM
June 30th AM
PM
9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3
1600
1200
800
400
0
Pipe empty
At this point the pipe was rapped three or four times smartly with a billet of wood
July 3d 12 4th 12 5th 6th 7th 8th 9th 10th 11th 12th 13th 14th 15th 16th 17th 18th

ENGINEERS' CLUB OF ST. LOUIS.

ORGANIZED 1868.

TRANSACTIONS.

THE ENGINEERS' CLUB OF ST. LOUIS.

This body commenced its existence by a meeting held at the office of the Water-Works Board on November 4, 1868, at which Mr. Thomas J. Whitman presided, and Mr. William Eimbeck acted as secretary. Meetings were held weekly, and on December 2, 1868, a permanent organization was made, and Col. Henry Flad was elected President; Mr. Frederick Shickle, Vice-President; Mr. Joseph P. Davis, Treasurer, and Mr. George P. Herthel, Jr., Secretary.

The Club was duly incorporated on April 12, 1869, filing in the office of the Clerk of the Circuit Court of St. Louis County their articles of association, in conformity with an "Act concerning corporations," approved March 19, 1866, under the name and style of the "Engineers' Club of St. Louis, Mo."

The incorporators named were: Henry Flad, George W. Fisher, Thomas J. Whitman, L. Frederick Rice, T. A. Meysenburg, William Eimbeck, Charles Pfeifer, C. E. Ilsley, George P. Herthel, Jr., Joseph P. Davis, and James Andrews.

In January, 1872, an arrangement was made with the Board of Public Schools, by which a room was provided in the building belonging to said Board, once a week, which continued up to 1881. Weekly, monthly and called meetings have been tried, the latter plan seeming to be the best in results.

Col. Flad was re-elected President until December, 1880. The officers for the year 1881 were: Thomas J. Whitman, President; C. Shaler Smith, Vice-President; E. D. Meier, Treasurer; Charles A. Smith, Secretary.

REPORT OF M. KELLER UPON A MEMOIR PRESENTED BY M. O. HALLAUER UPON "STEAM-ENGINES."

[The following translation was read before the Engineers Club, of St. Louis, January 5, 1881, and as the Bulletin de La Société Industrielle de Mulhouse is not commonly circulated in the United States, it has been thought worth while to print. The effort has been to preserve the form of the original thought as closely as possible.]

GENTLEMEN: The work of M. Hallauer, of which I have the honor to present to you a summary, is, as its title indicates, a study of the economic influence of the degree of expansion (point of cut-off) in various types of steam-engines. It tends also to support by analyses more and more numerous the conclusions of the last paper of the author, that is to say, the equality in the matter of industrial consumption of simple and compound engines, the advantage being rather on the side of the former.

It is divided into three parts: the first comprising researches relative to double cylinder engines, the second concerning single cylinder engines, the third summing up and comparing the results obtained. We will follow M. Hallauer successively in the order adopted by him in the study which occupies us, viz., first, the compound, then the simple engines, and, summing up for each type, we will conclude upon the whole work.

FIRST PART.—DOUBLE CYLINDER ENGINES, CALLED "WOOLF" (OR COMPOUND).

M. Hallauer states first all that has been said concerning the advantages of this system, and after discussion arrives at the conclusion that the only consideration "a priori" truly serious which cannot be gainsaid, which militates in its favor, is this:

That the difference of force at the commencement and at the end of the stroke is less great than for other types of engine, and that in consequence of this better distribution the progress of the machine is much smoother. Concerning the useful effect of the compound engine, the brake experiments executed under the auspices of your mechanical committee have shown that the "Woolf engines" absorb more force in themselves than single cylinder engines, a result easily foreseen.

Passing then to the study of the influence of the cut-off in the small cylinder, M. Hallauer commences by verifying the results obtained—

First. In a series of experiments executed by himself in 1877 with a Woolf beam engine situated at Münster, and coming from the shops of the Alsatian Society for the Construction of Machines.

Second. In the experiments executed in 1876 under the auspices of your Mechanical Committee upon a horizontal Woolf engine of the same make, which have appeared in the bulletin for July-August, 1877.

Third. In those executed in February, 1877, by the Alsatian Association of Steam Owners upon an engine at Malmerspach coming from the same constructors, but provided with a variable expansion in the small cylinder, controlled by the governor and established by the machine company of Bitschwiller-Thaun.

Fourth. In the experiments executed at St. Remy by M. Quém and at Rouen by the Norman Association of Steam Owners, upon two Woolf beam engines, from the shops of Messrs. Thomas & Powell, of Rouen.

Having eliminated the experiments of which the verification is not exact enough, M. Hallauer determined the consumption of dry saturated steam per hour, and for each absolute horse-power, per indicated horse-power per hour, and per effective horse-power per hour, basing himself upon the sum of the calories* brought into the cylinder by the steam and water leaving the boiler; in other words, substituting for the entrained water the quantity of steam which could furnish to the cylinder the same number of calories which had been brought by that water, and holding account of the calories left in the jacket by the steam which there condensed. He passes then to the analysis of each experiment, and determines the quantity of steam and water contained at the end of admission and at the end of the stroke; the variations of the internal heat, and finally of the cooling in the condenser Rc.† This cooling is verified by two different methods, already exposed many times by Mr. Hallauer in your bulletins.

I should stop a moment to say some words upon the verification of the experiments.

M. Hallauer's very elegant manner of operating has already been given in his last work. However, I believe it is not useless to speak again of it here in order to clearly comprehend its importance.

When it is wished to render an account of the quantity of steam expended during a given time by an engine, the water fed to the boiler is measured. This quantity of water, augmented or diminished by a weight easily calculated, according as the level in the boiler is more or less at the end of the experiment than it was at the beginning, gives the quantity of steam employed. A method given by M. G. A. Hirn, and many times developed in your bulletins, permits the determination of the proportion of water entrained with this vapor. This constitutes the direct gauging, which is verified by the following method:

Knowing the weight of water and of steam leaving the boiler and the pressure of steam therein, it is easy to determine the number of calories brought to the engine per stroke. This number of calories, diminished by the external cooling and the heat absorbed by the work done, should be equal to the number of calories absorbed by the water of condensation, a quantity obtained by gauging the water leaving the condenser, and measuring the initial and final temperature. The manner of operation has been many times described. The difference between the number of calories brought to the engine diminished by the work done and by external radiation, and that of the calories found in the condenser divided by the total number of calories, gives the per cent. of error which has been committed.

A word also concerning the term "absolute horse-power" which has not always been easily understood.

The fine work of M. Hirn has shown the enormous influence of the

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* A calorie is $0.5 \times 2.204 = 3.9672$ British heat units.

† NOTE.—I understand by Rc the cooling effect of the condenser upon the steam in the cylinders.

sides of the cylinder upon the action of the steam therein contained. When two engines of different types and dimensions are compared, or the work of the same engine under varying conditions, it is the influence of the internal surfaces which should be determined to render an account of the manner in which the steam is utilized in each experiment. But whatever system of condenser is used the influence of the internal surfaces can only vary little; but on the other hand, the vacuum may vary within wide limits, and consequently the indicated work: the variable vacuum, being a point to be considered if one compares engines by their indicated horse-power, can falsify the comparison. We are then forced to suppose that engines, which it is wished to compare, are furnished with an ideal condenser keeping a perfect vacuum behind the piston, and to compare between the engines an account of the work furnished with this perfect vacuum. That is the work which constitutes the absolute work of the engine, and it is the consumption for this absolute work which permits the comparison between different engines or of different condition of working.*

It is well understood, for the rest, that from the practical and industrial point of view the better the condenser the better the results; this is the affair of the constructor, but can have little influence upon the manner in which the steam comports itself in the interior of the cylinder.

The absolute work is then the term to be employed for comparison of two engines of different types, or working under different conditions, but the effective work will be always the term of comparison to be employed from the industrial point of view.

This stated, I sum up in the following table the results of the verifications and analyses of M. Hallauer, and I arrive with him at the deductions shown. (See page 21.)

The experiments executed upon the engine at Münster, in which the variation of work is obtained by throttling, give as the difference of consumption per absolute horse-power per hour for the extremes of work 3 per cent., which represents the effect of throttling.

In passing to the effective horse-power per hour the economy is much more considerable, and reaches 20 per cent., which shows the influence of the back pressure measured with the work done, and the co-efficient of friction which augments in the same circumstances.

M. Hallauer has then reached the conclusion in his preceding work that the most simple process of regulation is an expansion valve regulated by hand and the governor throttle, the control by hand being used for the larger variations and the throttle for maintaining the speed uniform in spite of the minor variations of work which occur every instant.

The author also explains by simple considerations, based always upon the action of the internal surfaces, some apparent anomalies which seem to occur in the experiments. I will not enter into these details, which would force us to give here the entire work, they all prove that the practical theory pointed out by M. Hirn and applied here by M. Hallauer permits the explanation of all the phenomena which take place in the interior of cylinders. After having studied the condensation and evapora-

* In English it is usually called the total or forward work.—TRANSLATOR.

COMPOUND ENGINES—FRENCH UNITS.

	Engine at Munster.			Engine at Malmerspach.					Vertical Woolf.		Thomas & Powell.	
	Expt. I.	Expt. II.	Expt. III.	Expt. B.	Expt. C.	Expt. D.	Expt. E.	Expt. F.	Weak Load	Full Load.	Expt. A. Nde.	Expt Quem.
Degree of expansion	1-9	1-7	1-7	1-6	1 13	1-13	1-28	1-25	1-6	1-6	1-22	1-19
Indicated horse-power	347	267	185	201.6	215	219.92	143.11	149.53	130	181	....	137
Per cent. error committed, found by verification	1.25	0.23	1.2	2.8	4.9	2.9	3.2	2.5	1.13	0.6	9	3.5
Steam per absolute H.P. p. h.	7.112	6.945	7.384	7.402	6.878	6.983	6.731	6.821	7.290	7.328	....	6.840
" indicated " "	8.614	8.739	9.730	8.847	8.149	8.210	8.273	8.260	9.120	8.878	....	7.591
" effective " "	9.864	10.357	12.411	10.301	9.465	9.517	10.011	9.898	10.563	9.975	....	9.762
Proportion condensed in jacket	8.6	9	10.4	5.1	7.7	....	8.5	....	10	10.8	....	....
Per cent. water in steam at end of admission	16.17	14.21	21.17	12.8	23.7	....	40	....	11.2	10.8	....	....
Per cent. at end of stroke in the small cylinder	19.1	....	....	....	13.1	....	19.1	....	....	....	....	....
Per cent. at end of stroke in the large cyclinder	6.6	5.39	7.39	11.5	17.9	....	17.6	....	5.34	4.5	....	....
Per cent. back pressure work to forward work	17.43	20.52	24.1	16.4	15.6	14.9	18.6	17.5	20.06	17.3	....	9.9
Rc	21.89	6.65	13.48	8.44	31.44	....	19.34	....	1.95	1.16	....	....
Heat rejected in per cent. of that received	3.38	1.32	3.5	2.1	8.3	....	7.8	....	1.19	6.5	....	....
BRITISH UNITS.												
English I H.P	342	263.3	182.4	198.8	212	217	141	147.4	128	180	....	135
Pounds water per hour forward H.P	15.67	15.31	16.27	16.31	15.16	15.39	17.04	15.03	16.07	16.15	....	15.07
Pounds water per hour I H.P	18.98	19.26	21.45	19.50	17.96	18.10	18.23	18.20	20 10	19.57	....	16.73
" " " E. H.P	21.74	22.83	27.354	22.70	20.86	20.98	22.04	21.81	23.28	21.98	....	21.38
Rc in heat units	88	26	54	33.6	125.6	....	77.2	....	7.6	4.4	....	....

Rc is heat radiated to the condenser by the cylinder.

tion in the interior of the small and large cylinders, and noting the considerable differences which occur from an expansion more or less prolonged in the small cylinder, M. Hallauer arrives at the important conclusions which follow, and which I sum up under a slightly different form from that which he has adopted.

First. Given a boiler working at 5.5 k.* of pressure, for instance, and a Woolf engine which can furnish a maximum work of *A* horse-power, there is a possibility of obtaining, industrially at least, 10 per cent. economy by cut-off in the small cylinder, instead of throttling down the steam at the times when, because of circumstances, the engine has to supply only the half of *A* horse-power; this economy will be diminished by the measure by which the work approaches to *A* horse-power.

Second. The engine working nearly to its maximum capacity, there can be produced by throttling a variation of force of 10 per cent. without any marked change in the economic régime.

We see at once the importance of these conclusions; in reality, there are few Woolf engines working at full power; furthermore, some builders of our region, when they furnish an engine, declare it at less than one-half less power than it really is.

Thus an engine sold at 100 H.P. can ordinarily furnish 200 H.P. without reaching its maximum. This mode of operation has practical advantages, but it is none the less true that when the engine only gives 100 H.P. that, thanks to the throttling, it consumes 10 per cent. more that it would have consumed if the work of 100 H.P. had been obtained by admitting full pressure and cutting off in the small cylinder.

I do not agree with M. Hallauer when he recommends a cut-off variable by hand. I believe that from the practical point of view a governor cut-off works better, for it disposes of the neglect of the engineer, who cannot very well give the desired cut-off the moment that it should be applied. We have nearly always observed that an automatic expansion procures a more regular speed than a governor throttle.

SECOND PART.—INFLUENCE OF CUT-OFF IN SINGLE CYLINDER ENGINES.

M. Hallauer proceeds for these engines as he did for the compound engine. He verifies the experiments first upon which he rests; then he analyzes them.

The documents which have served for this study came from the following experiments:

First. Those executed under the auspices of your mechanical committee in April and May, 1878, upon a Corliss engine, constructed by Messrs. Berger, André & Co., of Thann.

Second. Those undertaken in 1873 and 1875 by Messrs. Hallauer, Grosseteste and Dwelshauvers-Dery, under the inspiration of M. G. A. Hirn, and executed upon an engine deprived of its jacket, and working with superheated and with saturated steam. We group the results of the verifications and analyses in the table which follows. (See page 23.)

The examination of these results shows:

First. That for the Corliss engine, with steam jacket, there is a theoretical economy per absolute horse-power of $1\frac{6}{10}$ per cent. when the

* 14.223 lbs. per square inch = 1 k per square centimetre.

SINGLE CYLINDER ENGINES.—FRENCH UNITS.

	Corliss, with Jacket.			Hein Unjacketed.				
	Saturated Steam.			Saturated.		Superheated Steam.		
	I.	II.	III.	I.	II.	I. 196°.	II. 231°.	III. 273°.
Degree of expansion	1-11	1-8	1-6	1-7	1-4	1-7	1-4	1-2
Indicated horse-power	105	137	158	107	146	113	154	125
Per cent. error committed	3.1	2.3	2.4	0.1	0.7	0.6	9.8	0.6
Steam, p. A. H.P. p. h.	7.188	7.236	7.307	7.822	8.449	6.655	7	7.874
" p. I. H P. p. h.	7.983	7.939	7.955	8.837	9.367	7.370	7.633	8.655
" p. E. H.P. p. h.	9.071	8.724	8.646	9.929	10.341	8.188	8.207	9.511
Per cent. condensed in jacket	6.5	6	5.3	....	....	....	....	....
Per cent. water at end of admission	38.3	31.7	25.3	37.0	31.0	24.6	6.5	superheated.
" " " expansion	21.7	19.2	18.5	35.2	25.2	21.4	12	13.2
Rc, heat radiated to the condenser by the cylinder	11.21	11.14	11.15	37.01	37.53	18.80	16.61	20.34
Rc in per cent. of heat received	12.3	9.8	8.0	21.6	15.4	12.5	7.8	10.5

BRITISH UNITS.

	I.	II.	III.	I.	II.	I. 196°.	II. 231°.	III. 273°.
British I H. P	104	135	156	106	144	112	152	124
Pounds water per hour total H.P.	15.84	15.95	16.10	17.24	18.61	14.67	15.43	17.354
" " " 1 H.P	17.59	17.50	17.53	19.48	20.32	16.24	16.82	19.075
" " " Eff. H.P.	19.99	19.23	19.05	21.88	22.79	18.05	18.09	20.96
Rc heat units	44	44	44	148	148	73	65	80

cut-off is changed from $\frac{1}{6}$ to $\frac{1}{11}$, but that industrially this economy disappears and changes sign, and that there is a practical gain per effective horse-power of $4\frac{1}{2}$ per cent. by working at $\frac{1}{6}$ cut-off in place of $\frac{1}{11}$.

Second. That for the engine, without jacket and without superheating, the economy furnished by the cut-off is much more considerable than the Hirn engine working with saturated steam, and that there is a theoretic gain of 7.4 per cent. by changes to cut-off $\frac{1}{7}$ from $\frac{1}{4}$, and that industrially this economy remains at 4 per cent.

Third. In holding account of the difference of superheating, the experiments I. and II. (196° C. and 231° C.) establish that the influence of the cut-off in the unjacketed engine, with superheated steam, remains as it did with saturated steam.

Experiment III., with superheated steam, shows still more the great economy of the cut-off in these circumstances, where one passes certain limits, for between admissions of $\frac{1}{2}$ and $\frac{1}{7}$ there is 15 per cent. economy, which would have been more considerable if in experiment I. we had worked with the same superheating as in experiment III.

Fourth. In the Hirn engine the experiments with saturated steam give at the end of the stroke the same weight of water, 0.0940 k.* and 0.0927 k. and the refrigeration is also the same, 37.53° C. and 37.02° C., while without any jacket the same weights of water gave the same values of Rc. For the Corliss engine, on the contrary, the weights of water differ at the end of the stroke, 0.0298 k. and 0.0398 k., and the same refrigeration, 11.21° C. and 11.15° C., results showing the steam jacket. For experiments II. and III., with superheating, the weights of water at the end of the stroke are 0.0367 k. and 0.0373 k., and the refrigerations 16.61° C. and 20.34° C., a difference which should be attributed to superheating, for in the same conditions saturated steam rejects in the condenser heat according to the weight of water evaporated at the end of the stroke. This shows that superheating acts in a different manner from jacketing.

Analyzing the variations of internal heat in the various experiments which occupy us, and the values of the refrigeration in the condenser, which result from differences of cut-off, according as they work with or without a jacket, and with or without superheating, M. Hallauer comes to the same conclusion as to the different modes of action of the jacket and superheater. The jacket acts more energetically than the superheater, and in the same kind during the period of expansion, but becomes disadvantageous during that of condensation, for then it furnishes heat to the water which lines the internal surfaces of the cylinder, and augments that rejected into the condenser, which is not the case with superheating, and which renders the latter more economical in most cases. Examining, then, the theoretic economy, and comparing the consumption per absolute horse-power per hour, and the industrial economy and the amounts per effective horse-power per hour, the author agrees with M. Zeuner that large expansions are economical from a theoretical point of view, and with M. Hirn that the reverse is the case from an industrial standpoint.

Thus the conclusions of these two savants, which had the air of contradiction are found to be in accord, holding account of the different

* 1 k. = 2.204 lbs.

considerations which have guided them; the one, M. Zeuner, having made a general study of steam engines based upon conditions non-realizable (non-conducting internal surfaces of the cylinder), the other, M. Hirn, on the contrary, having studied them from the industrial base, and holding account of the action of the internal surfaces and the work done in friction.

THIRD PART.—COMPARISON OF THE DIFFERENT TYPES OF ENGINE STUDIED.

The close of M. Hallauer's work includes the comparison of compound and simple engines; taking always the analysis of the experiments which have served for the two first parts of the work, he restates what he understands by absolute indicated and effective horse-power.

The absolute work is the work which would have been given by the engine with an ideal condenser, making a perfect vacuum behind the piston (the theoretical work).*

The indicated work is that furnished by the steam upon the pistons ; it holds account of the influence of the back pressure (it is the work which the diagrams traced by the indicator enable us to calculate).

The effective work is then the work industrially disposable ; it takes account of the back pressure and the friction of the various parts of the engine itself.

That stated, there are two of the verified experiments ; one executed upon the Corliss engine, cutting off at $\frac{1}{6}$, the other on the Malmerspach engine, cutting off at $\frac{1}{13}$, of which the figures approach each other as closely as possible.

	Corliss.	Woolf.
Water contained at the end of admission....	$25\frac{3}{10}$ per cent.	$23\frac{7}{10}$ per cent.
" " " " expansion....	$18\frac{5}{10}$ "	$17\frac{9}{10}$ "
Difference of initial and final heat............	$1\frac{83}{100}°$ C.	$1\frac{24}{100}°$ C.
Rejected in condenser.........................	$8\frac{3}{10}°$ "	$8°$ "

The comparison of these two experiments brings us to very interesting conclusions.

A phenomenon to be first noted for the Woolf engine destroys a false idea held hitherto : that for the double-cylinder engine a portion of the force is withdrawn from the cooling influence of the condenser.

In reality, in the small cylinder the expansion from half stroke gave place to an evaporation of 10.6 per cent. of the weight of water contained at the end of admission, and the internal heat increased much more rapidly than in the Corliss engine. Then the mixture of steam and water passed to the large cylinder with 13.1 per cent. of water, and in place of the evaporation continuing in this cylinder there was, on the contrary, condensation, in spite of the jacket, till at the end of the stroke 4.8 per cent. more water deposited than at the end of the stroke in the small cylinder. This shows that the great condensation at the moment of entrance in the large cylinder is strong enough, in spite of the jacket ; that all the steam condensed in the large cylinder, and that which has come from the small cylinder, cannot be evaporated.

In the Corliss engine, on the other hand, there is a continuous evaporation till the end of the expansion. We see that the influence of the

* The forward work.—TRANSLATOR.

large cylinder in the case of expansion, commenced in the small cylinder, does not always tend to lessen the rejected heat, but, on the contrary, may sometimes augment it, which is the reverse of that which has been hitherto admitted.

The consumption of dry saturated steam per absolute horse-power per hour gives the theoretic economy realized by the one or other motor. If we compare the consumption of the Corliss with that which it would have had with an expansion of 13, which is that of the Woolf engine, for the experiment with which we compare, we find that the theoretic economy is 4 per cent. in favor of the Woolf engine; but the influence of the back pressure, and still more that of the friction, reduces this economy when we pass into the industrial domain. It then changes sign, and we find that the practical economy becomes 8.7 per cent. in favor of the Corliss.

Comparing, then, the horizontal Woolf engine with the Corliss, and holding account of the lack of compression in the former, M. Hallauer finds again a theoretic economy of 4 per cent. for the Woolf engine, but that economy also disappears in practice, and the Corliss becomes industrially superior by 9.05 per cent. to the horizontal compound. Meanwhile, holding account of the construction of this latter, the difference falls to 2 per cent., and then the horizontal Woolf engine consumes only 8.8 k. of dry saturated steam per effective horse-power per hour, which is the smallest to which we can arrive by a careful construction of condenser, and a very strong compression. In closing, M. Hallauer sums up in a table the consumption of steam per hour per horse-power, absolute, indicated and effective, adding the consumption per effective horse-power per hour of coal, on the basis of an evaporation of 8.

The table shows that the various types of double cylinder engines consume from 9.1 to 9.5 k. of steam per effective horse-power per hour; the Corliss, with cut-off $\frac{1}{6}$, only uses 8.6 k., while the Hirn engine, with superheated steam, with $\frac{1}{7}$ cut-off, only uses 8 k. [17.6. lbs. C. A. S.].

In summing up: The work of M. Hallauer, which is one of those laborious and conscientious studies to which he has from long since accustomed our society, is very remarkable above all in its conclusions and tends once more to prove the impossibility of stating anything with precision concerning steam-engines, if one is not resting on verified experiments of existing engines.

We have had in this summary to leave by the side many interesting things, seeking mainly to unite the divers conclusions of M. Hallauer; but all parties concerned in steam-engines will certainly find in his work exceedingly useful material which can serve in many circumstances. We are then cognizant of owing many thanks to M. Hallauer for all these studies which demand so enormously time, patience, and reflection, all things of which he has not been sparing in this his last memoir; you know for the rest what he is accustomed to do, by the numerous works which he has already presented to our society, and of which this last gives in a manner the most interesting practical conclusions.

EXPLOSIONS OF FLOUR DUST.

By William Cordes, Member of the Club.

Read April 13, 1881.]

That fine dust, flour, or other dry carbonaceous matter, when in suspension in air will burn very rapidly, has been known for some time. Such combustion is so rapid that when the air is confined an increase of pressure follows the increase of temperature, and the effects are manifest as an explosion.

In 1872 a very serious explosion took place in a flour-mill near Glasgow, Scotland, by which fourteen were killed and twelve wounded more or less severely. The inquest was attended by an investigation in which Mr. Stevenson MacAdam and Prof. W. J. M. Rankine were employed as experts, and they reported that this class of accidents was by no means uncommon, and could happen while there was no unusual work or risk of fire occurring.

The report recommends that flour-mills be constructed with the dust-rooms apart from the building, and of such light material that the damage by the explosion shall all be concentrated at this place and that renewal shall be easy and shall not be expensive.

In spite of this investigation and the eminence of the persons making such recommendation, little heed was paid to the matter, at least in the United States, until in 1877 the calamity at Minneapolis, Minn., again directed attention to the fearful risk taken with a material which in the older processes was perfectly free from danger, but which by the very endeavor to improve became more nearly like gunpowder than anything else.

On February 23, 1881, an explosion took place in the Camp Spring Mill in St. Louis, which seems to very strongly establish the wisdom of the Glasgow experts, and to place their conclusions beyond all question. This explosion took place at 8 P. M., and it has been thought worth while to place it upon record. especially as many of the facts are clearly known and established, and are not involved in the usual mystery.

At the time there were on duty five men, whose stations were as follows: First, the engineer, who also acts as fireman, on the ground floor at the northeast corner of the building; second, the miller, who has general charge, and who goes all through the mill proper at least twice an hour; third, the oiler, who goes to all the faster journals to oil and inspect about once in two hours; fourth, the packer, who is stationed on the second or grinding floor and who handles and heads up the barrels; fifth, the barrel nailer, who acts as helper to the packer, and remains on the grinding floor.

At the time of the explosion all the men but the engineer were on the grinding floor, when one of the crushing rolls began to make an unusual noise; the miller started to throw off the belt driving this crusher, when the middlings caught fire and the explosion followed instantaneously. The gas lights throughout the mill were extinguished. The dust-room

was situated at the northeast corner of the mill, over the engine-room, and had no other connection with the mill than a 16-inch galvanized iron pipe, which connects with a Sturtevant suction fan, and by branches to the crushers. From the dust-room to the fan is about 10 feet, and from the fan to the crusher about 35 feet. The branch is 25 feet of 4-inch tin pipe.

The dust-room was 11 × 12 × 34 feet high, with four compartments, wi hatchways 3 feet square in each of the three dividing floors. The du conduit entered about 5 feet from the bottom floor, which was the roo of the engine-room, and the air outlet was a ventilator at the top about 4 × 6 feet, with 6 feet height and louvre slats on all four sides. The lower floor was $\frac{7}{8}$ inch, with joists 2 × 6 inches, 16-inch centres resting on the roof of the engine-room. The sheeting of this roof was $\frac{7}{8}$ inch, with joists 2 × 12 inches, spaced 16 inches. The south side of the dust-room was the mill wall of brick, the lower 18 feet being 13 inches, the upper portion being 9 inches, excepting the upper 2 feet, which was wooden. The other three sides were alike; upright studding 2 × 4 × 18 inch centres, carrying sheeting $\frac{7}{8}$ inch, covered with light sheet-iron. The west wall separated the dust-room from a portion of the mill which had been added later and was used for bolting. The north and east sides were clear.

The explosion carried away the north and east sides entirely, some portions to a distance of 100 feet, but the greater part about 50 feet. The north side of the bolting-room was moved out about 4 feet, and a piece 34 feet high and 22 feet long was left standing against the stack (which it nearly demolished); over the boiler-room, just north of the engine-room, the roof of the bolting-rooms falling, as did the roof and ventilator of the dust-room, nearly vertically. The débris took fire, and was soon extinguished without further damage.

An examination of the machinery revealed that the crusher from which the fire originated had broken the porcelain covering of one of the rolls, a piece falling between the rolls and causing the fire by friction and igniting the finely divided material which was drawn by the fan and thrown into the dust-room. The draft of the fan was so powerful that the material in the other branches did not ignite back to the other crushers, but the flame passed through the fan to the dust-room, where the ignition produced the results described. The shock to the fan threw off the belt driving it, and put out the lights.

The reconstructed dust-room is similar, but is made as light as possible in the hope that a similar explosion will be followed by no more serious consequences. The mill was stopped ten days, and the damage was $1,600. Had the dust-room been placed in the interior of the mill, or had it been inclosed by brick walls, as it usually is, the destruction of the entire mill would have certainly followed, and another mysterious fire in a flour-mill would have been added to the list by which St. Louis is already known to the insurance companies.

PROCEEDINGS.

April 13, 1881 :—The two hundred and fifth meeting of the St. Louis Engineers' Club was called to order by the Vice-President, C. Shaler Smith.

The Committee on Quarters for the Club reported and was continued, with instructions to ascertain upon what terms quarters can be obtained from the Mercantile Library, and to call a meeting after obtaining such information.

A report received from the Committee on Joint Publications moved that the sense of the meeting is that the offer of the *American Engineer* is best adapted to the present need of the Association of Engineering Societies.

Messrs. J. F. Wangler and John Sobolewski were duly elected as members.

A paper on the Explosion of Flour Dust at the Camp Spring Mill, by Mr. Wm. Cordes, was read, and discussed by Messrs. Meier, Smith, McMath, and Moore.

The thanks of the club were given to Mr. Cordes for his paper.

Gen. Smith then described the proposed means of ventilating the tunnel, and a discussion took place by Messrs. Meier, Pond, McMath, Smith, and Moore.

Mr. McMath exhibited some diagrams showing the mean velocity of water flowing in open channels, which was discussed by Gen. Smith, Messrs. Meier, Moore, and White.

Mr. Wm. Cordes was proposed as a member of the club by Messrs. White and Pond.

WESTERN SOCIETY OF ENGINEERS.

ORGANIZED 1869.

TRANSACTIONS.

WESTERN SOCIETY OF ENGINEERS.

In response to an invitation from Col. R. B. Mason a meeting was held in Chicago on the evening of Tuesday, May 25, 1869, for the purpose of organizing an Engineers' Club.

The gentlemen present were R. B. Mason, K. F. Booth, I. C. Chesbrough, Wm. H. Clarke, H. A. Gardner, Max Hjortsberg, Charles Paine, George C. Morgan, L. H. Clarke, A. S. Van Meenen, Wm. Bryson, and L. P. Morehouse. By resolution the name taken was "The Civil Engineers' Club of Chicago." At the next meeting, the second Monday in June, Messrs. Paine, Hjortsberg and W. H. Clarke reported a plan of organization. A constitution was adopted, the name being changed to "Civil Engineers' Club of the Northwest."

Col. R. B. Mason was elected President and L. P. Morehouse, Secretary.

The Presidency has been held successively by R. B. Mason, Charles Paine, E. S. Chesbrough, and Gen. W. Sooy Smith, and again by E. S. Chesbrough.

The Secretaryship has been held continuously by L. P. Morehouse.

A new constitution was adopted and the name changed to "Western Society of Engineers" by a vote of the club on June 1, 1880.

Under the present name it has become incorporated by the laws of the State of Illinois.

The present officers of the Society are: E. S. Chesbrough, President; Moses Lane, First Vice-President; D. C. Cregier, Second Vice-President; L. P. Morehouse, Secretary; Col. Charles Fitzsimons, Treasurer; John W. Weston, Librarian; Trustees, H. C. Nutt, S. S. Greeley, and R. J. McClure.

In the twelve years of the existence of the Society there have been 132 regular meetings held, and 118 professional papers read before the meetings.

It has steadily progressed in numbers and influence since its organization, and now has upon its roll 122 active members and 4 associate members.

Its meetings are held semi-monthly at the rooms of the Western Railroad Association in the Honoré Block, Chicago.

HUDSON RIVER TUNNEL.

By Wm. Sooy Smith & Son, Members of the Society.

[Read Oct. 5, 1881.]

The great need of the Hudson River tunnel results from the fact that, with the single exception of the New York Central, all the railways from the West and South to New York terminate on the west bank of the Hudson River, and the freight and passengers carried by them have to be ferried across to the city. This ferriage is expensive, and during the winter time difficult, on account of the ice in the river. The volume of railway traffic subjected to this embarrassment is very great and rapidly increasing.

A double tunnel affords the most practicable method of providing a channel for it which shall be free from any obstruction or interruption.

The construction of such a tunnel was commenced by D. C. Haskin in the middle of September, 1874. In one month from that time a weary litigation commenced in an injunction restraining him from the further prosecution of the work. This litigation lasted for years, and it was not until August, 1879, that work was resumed. Since that time it has been vigorously pushed, and has progressed without interruption except by one serious accident, which occurred July 21, 1880.

A shaft had been sunk and an air-lock set in the wall of this shaft. A passage had been constructed from the outer end of this air-lock, widening and descending as it advanced, until the proper depth and width were obtained for the commencement of the tunnel. This passage was lined with iron plates held in position by braces. After the north tunnel had been carried forward 260 feet, as stated, an effort was made to enlarge the passage to the full size necessary as an entrance to the tunnels from the shaft. The space above the entrance was partly filled with cinders and other loose materials, through which the compressed air escaped. The plates, deprived of the supporting power of the compressed air, fell in, burying twenty of the workmen who were unable to get into the air-lock, the door of which was partly closed by the fallen plates. Eight men who got into the air-lock before this occurred escaped.

An effort was made to sink a coffer-dam to the required depth to recover the bodies and repair the damage, but this having failed, a pneumatic caisson was sunk, the bodies recovered, and connection made between this caisson and the air-lock of the working-shaft on one side, and with the two tunnels on the other. Work was then prosecuted on each of these tunnels alternately, until the south tunnel was advanced 450 feet and the north tunnel 448 feet. The south tunnel was, at its outer extremity, 5 feet lower than the north tunnel, and the air pressure

necessary for successful work in the south heading was so much greater than that needed in the north heading, and so much in excess of the hydrostatic pressure on top of the shallower parts of both tunnels, the grade descending rapidly, that it became necessary to build bulk-heads in both tunnels in order to supply just the pressure required in each. Up to the time of the completion of these bulk-heads, the whole of the completed parts of both tunnels and the caisson from which they start was one vast air-chamber, and the leakage of air through the porous brick-work lining and up through the overlying materials was so great as to give much extra labor to the compressors. The bulk-head walls are of brick, four feet in thickness, backed by a solid wall of timber twelve inches thick, and strongly braced with timber braces let into the brick work. There are two air-locks placed in each bulk-head, each of which will contain all the workmen employed at any one time in either heading. One of these air-locks is kept open toward the heading at all times, to provide a place of refuge for the men in case of necessity. The movement of the material in which the work is going on is so slow, even when the air pressure is greatly reduced, that the men have ample time to avail themselves of the means provided for their escape to the rear of the bulk-heads into the completed part of the tunnels. All chance of silt or water entering this part of the work is prevented by the bulk-heads, which are air-tight, and of course water-tight.

It will now be proper to describe the tunnels and the mode employed to construct them. Each tunnel has a vertical diameter of 18 feet, and horizontal diameter of 16 feet inside measurement. It is surrounded by a wrought-iron cylinder ¼ inch thick, consisting of plates united by bolts passing through flanges of angle-iron. This cylinder is lined with two feet of brick-work, consisting of best Haverstraw brick laid in Portland cement mortar, consisting of one part cement and two parts clean, sharp sand. Recently a portion of the south tunnel has been lined a little more than half way up from the bottom with the same thickness of concrete, consisting of one part Portland cement, two parts sand and four parts small angular broken stone, the upper part of the tunnelbeing lined with brick-work as before, except the inside five inches, which consists of asphalt blocks; these blocks being used to prevent any escape of air. The completed part of the tunnel being filled up to the level of these blocks with silt, during the construction of the work no air can escape through the cement lining below. This promises to make a stronger and better lining than the brick-work, and at present prices of material it is considerably less expensive. The grades adopted are from two to three per cent.

The water in the river is 62 feet deep at the deepest, and the tunnel will be 20 feet below bottom at this deepest point. The material of the river bottom is silt, of very uniform character throughout a distance of four thousand feet from the Jersey shore—and from this to the New York side, a distance of fourteen hundred feet, it is silt, underlaid with sand and rock in place. The following is an analysis of this material, made by Albert R. Leeds, Professor of Chemistry of the Stevens Institute.

The original sample (taken from the heading) contained 33.18 per cent. water. An analysis performed on the sample after drying gave :

	Per cent.
Combined water	5.13
" silica	58.95
Free silica or quartz	10.32
Alumina	15.14
Protoxide of manganese	0.95
" of iron	3.28
Sesquioxide "	1.38
Lime	2.88
Magnesia	1.50
Sodium combined as chloride	0.23
Chlorine existing in the form of chloride	0.38
Sulphuric acid	trace
Titanic acid	trace

As its composition would indicate, it is a compact, tenacious stuff. It is finely comminuted and both air and water pass through it very slowly. When it contains one-third water, as in the sample above, it has about the consistency of stiff putty, and shrinks greatly in drying, and where it has been exposed at the heading for a length of time to air pressure the water is slowly pressed back through and out of it, until it shrinks, cracks, and falls down. But in its moist condition it is an excellent puddling material to hold either air or water.

When exposed to air pressure of 20 pounds to the square inch it requires an additional pressure of 2,700 pounds to the square foot to force a disk into it, this pressure being accompanied by vibration. Its total resistance to displacement at a depth of 60 feet below water surface (at which depth experiments were made to determine this resistance) would therefore seem to be 5,580 pounds per square foot. This is relied upon to insure the permanency of the work under the conditions of actual use. It is easy to make a cut into it $2\frac{1}{2} \times 5$ feet, and 5 feet deep, in order to place in position one of the plates of the iron shell.

The mode of carrying forward the work is as follows :

A pilot 6 feet 6 inches in diameter, consisting of plates similar to those of the outer shell, only smaller, is first carried forward into the heading. One plate is first placed in position at the top by opening a cut into the heading of sufficient size. This plate is supported by braces from the bottom of the cut. Another cut is then made on one side and a second plate slipped in, bolted to the first one, and supported like it by braces. A third plate is then put in position on the other side of the first one and similarly fastened in place. Other plates are then put in on each side, working from the top downward, until the first cylindrical ring of the pilot is complete. Then a second ring is put in in the same manner in advance of this, the plates of which are bolted to those of the first ring. After the pilot has been advanced in this way to a distance of 15 or 20 feet into the heading the plates of the outer shell are put in position in rings in the same way and braced in every direction from the pilot by radial braces. When four rings of plates, making 10 feet in length, have been placed in position in the shell they are lined with the brick-work or concrete lining, and the rear end of the pilot is strongly braced and held in position from this finished lining. This makes the rear end of the pilot immovable. The other end of the pilot resting in firm silt becomes fixed ; and the pilot itself, in addition to its usefulness in exploring the material in advance of the main heading,

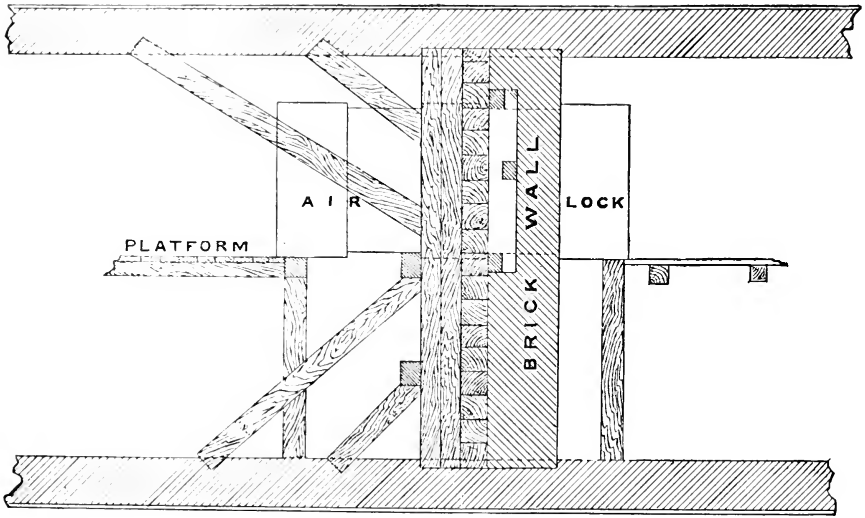
serves as a bridge from which the plates of the outer shell may be held in position. As the work progresses, plates are taken off the rear end of the pilot and carried to the front, where they are used as described in advancing the pilot.

Previous to the construction of the bulk-heads the excavation was done by puddling the silt with water into a semi-fluid state, and then forcing it out with air pressure. This method, now in common use both in this country and in Europe, was invented by the writer in 1859, and since patented by him. Since the completion of the bulk-heads, the work having been advanced to a considerable distance from the shaft, it has become desirable to aid this process by the addition of a powerful current of water forced through the discharge pipe, and for this purpose Capt. Eads' excellent sand pump is used.

The discharge pipe is brought sufficiently above the surface outside to give the necessary fall from the outlet to the dumping ground to cause the puddled material to flow to it without further trouble, so that no handling of it is necessary after it leaves the heading. On reaching the dumping ground it spreads out into settling basins, from which the clear water is permitted to flow back into the river after the silt has been completely dropped. To puddle the material a large box is used, surmounted by a smaller one with a wire screen bottom. The silt is thrown into the smaller box, where it is cut up by a powerful water jet. It then flows through the bottom into the larger box, where it is taken up by the suction from the Eads pump, aided by the air pressure in the heading. Passing through the pump it gets the impetus of the current of water flowing through the pump with a pressure of about 100 pounds to the square inch, and with this and the air pressure of about 23 pounds to the square inch it is carried forward through 450 feet of pipe and up through a height of 72 feet, where it is discharged into a tank, from which it flows to the dumping ground through a triangular wooden flume.

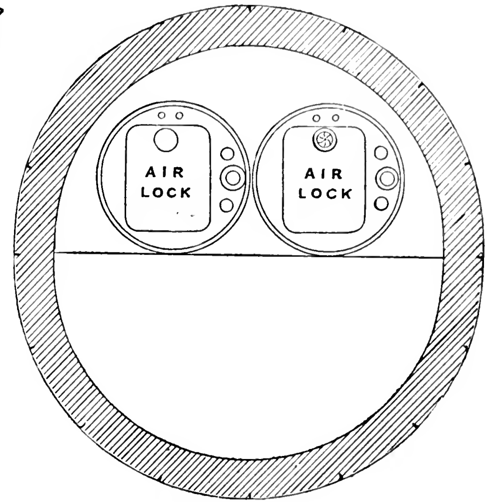
During these operations it must be remembered that the spaces in advance of the bulk-heads are air-chambers filled with compressed air, which serves to the extent of the pressure employed to sustain the envelope inclosing the air-chambers. This envelope consists of the bulk-heads, the finished lining of the tunnel, and the silt constituting the heading. The material is of the best possible character to make the air pressure available for this assistance to the bracing required to hold the plates in position until the lining is put in. It is nearly impervious to air, but not completely so. It is practicable to carry an air pressure at the heading equal to the hydrostatic pressure estimated from the top of the tunnel to the water surface. When the air pressure exceeds this the air passes slowly through the silt and escapes in bubbles at the water surface outside. The silt thus serves as a safety-valve to prevent the accumulation of a dangerous amount of air pressure.

As the compressed air balances only the weight of the column of water overhead, the surplus weight of the silt has to be resisted by the plates supported by bracing. The water of the Hudson at this point at mean high water weighs 63 pounds per cubic foot. The silt as it exists in the river bottom weighs 109 pounds per cubic foot. The surplus is therefore 109 — 63 = 46 pounds per cubic foot. Where the work is now going on the thick-



LONG^L SECTION OF BULKHEAD.

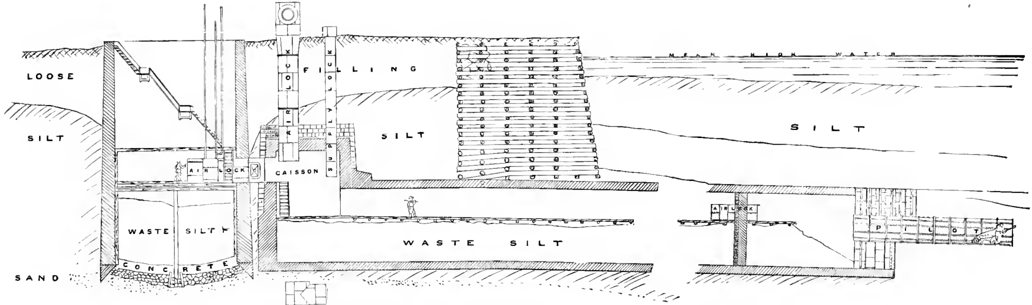
Scale 1/4 in. = 2 ft.

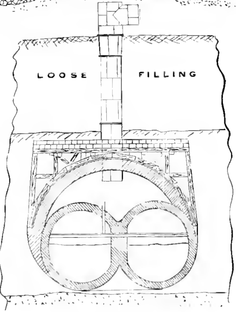


TRANS. SECTION OF BULKHEAD.

HUDSON RIVER TUNNEL

Wm. Sooy Smith & Son.



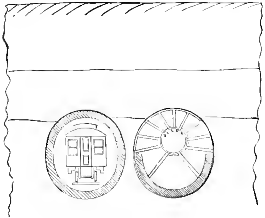


SECTION
N&S THROUGH
WEST END OF CAISSON

HUDSON RIVER TUNNEL

W Sooy Smith & Son

Scale 20' = 1"



SECTIONS
TUNNEL COMPLETED
TUNNEL IN CONSTRUCTION

ness of silt is 32 feet above the top of the tunnel. The total surplus weight held by the plates and bracing per square foot is therefore 1,472 pounds.

From this we should however deduct the resistance due to the consistency of the material, which we know to be very considerable—but although experiments made and in progress indicate the value of this resistance, they do not yet demonstrate its exact amount.

Careful borings have been made in great numbers, and the bottom thus explored until its character is well known. In addition to this, borings are made in advance from time to time, as the work proceeds, and steel rods are driven in advance of the pilots and main headings to prospect the material at every point.

Methods have been studied of overcoming almost any conceivable difficulty that may arise, and no room is left for doubt as to the ultimate success of the undertaking.

D. C. Haskin is the originator and contractor of the work; Wm. Sooy Smith & Son, Chief Engineers; S. H. Finch, First Assistant Engineer; C. W. Raymond, Second Assistant Engineer.

A caisson has been framed in position on the New York side, and the work of sinking it has just commenced. When the caisson has been sunk to the required depth, the two tunnels will be started from it and driven westward to meet those in progress from the Jersey side. The work can then be prosecuted in four headings simultaneously. The progress now made is from 2 to 5 feet per day in each heading. The total length of the tunnel, from shaft to shaft, exclusive of approaches, is 5,400 feet. The difficulties which have to be encountered and overcome are of a character which result from the imperfections which mark all human efforts, as compared with the perfect working of natural laws. Those engaged in designing, directing and doing this work may err or be careless. Nature makes no mistakes, and she is eternally vigilant. Troubles occur which cause delay and additional expense, but none can be foreseen which can greatly endanger life or threaten the enterprise with failure. Prudent management and persistent energy will accomplish the work in due time, and without more than the ordinary casualties attending great subaqueous operations.

PROCEEDINGS.

September 13, 1881:—The 131st regular meeting was held at 7:30 P. M., Vice-President Cregier in the chair.

The minutes of the preceding meeting were read and approved.

Application to be admitted as a member was presented by Mr. Max Zürcher, indorsed by Messrs. Randolph, Artingstall and Cunningham.

Mr. Benezette Williams presented the following resolution, which was seconded and adopted:

Resolved, That the Secretary of this Society is hereby authorized to pay to the Association of Engineering Societies the fifty cents entrance fee as provided in the Articles of Association; and that he is further authorized to pay an assessment of $1.50 per member for the use of the Association's publication as soon as he is officially notified that such assessment has been made by the Board of Managers of said Association.

The Secretary asked for instructions with regard to the payment of the entrance fee and the subscription to the publication of the Association.

Mr. C. J. Bates moved that the Secretary be instructed to pay the entrance fee on the full roll of membership at this date.

It was moved that the Secretary be instructed to pay the amount of $1.50 only for such members as have paid their dues.

Mr. Williams moved as a substitute that the Secretary pay this amount of $1.50 on the basis of actual membership.

This was seconded and adopted.

Mr. Morehouse presented the following as an amendment to the By-Laws:

BY-LAWS, ARTICLE IV, SEC. 9.

Any Member, or Associate, whose dues have not been delinquent for a consecutive term of five years, may, in case of absence from the country, or for any other cause which may prevent him from availing himself of the advantages of the Society, temporarily withdraw from active membership. During the term of such withdrawal Members, or Associates, shall not be liable for any dues or assessments, and shall not be entitled to the privileges of the Society.

Members, or Associates, temporarily withdrawing under this section, may return to active membership by giving notice to the Secretary of their desire so to do, and paying the annual dues for the current year.

The Secretary read a communication from the International Institute for Preserving Weights and Measures, which was referred to the Committee on Weights and Measures.

A paper, prepared by Mr. Edmund Wragge, Chief Engineer of the Toronto, Grey & Bruce Railway, and presented by Mr. Chanute, was read by Mr. Wright—"The Haggas System of Supplying Locomotives with Water." It was voted that the paper be accepted and placed on file, and the thanks of the Sceiety tendered to the author.

A paper was presented by Mr. Williams, written by Gen. W. Sooy Smith and Charles Sooy Smith, on the Hudson River Tunnel.

Owing to the lateness of the hour it was voted that this paper be published and discussed after its publication.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

October 4, 1881:—The 132d regular meeting was held at 4 P. M. Col. Fitzsimons was called to the chair.

The minutes of the preceding meeting were read and approved.

The Secretary read applications to be admitted as Members from John Alexander Low Waddell, Civil Engineer, Council Bluffs, Ia., indorsed by Messrs. C. J. Bates, W. S. Bates and W. S. McHarg; and from Clare Lovelace, Civil Engineer, No. 320 Fulton street, Chicago, Ill., indorsed by Messrs. Isham Randolph, A. V. Powell and C. J. Bates.

Mr. McHarg, Chairman of Committee on Papers, read a paper written by Messrs. W. Sooy Smith & Son —"The Hudson River Tunnel." The paper was illustrated with diagrams.

After discussion of the paper, upon motion, the meeting adjourned.

L. P. MOREHOUSE, Secretary.

October 18, 1881:—The regular meeting was held at 7:30 P. M. Mr. Benezette Williams was called to the chair.

The minutes of the preceding meeting were read and approved.

Mr. Max Zürcher, bridge engineer and contractor, No. 69 Dearborn street, Chicago, Ill., was elected a member.

The amendment to the by-laws, proposed at the 131st meeting, was brough up for consideration, and, after discussion, was adopted.

The Secretary reported, and exhibited, donations to the Society; from Mr. A.

Tallock a photograph of the Moscan River bridge, and from Mr. Lyman E. Cooley a series of photographs illustrating new methods of river improvement by use of wire screens.

Upon motion of Mr. Randolph, a vote was passed allowing Mr. W. F. Sargent, civil engineer Pullman's Palace Car Company, Pullman, Ill., to avail himself of his election as member, the legal term for qualification having expired.

It was voted that the subscription of the Society to the periodicals taken during the year be renewed for the ensuing year.

Adjourned.] L. P. MOREHOUSE, Secretary

CIVIL ENGINEERS' CLUB OF CLEVELAND.

ORGANIZED 1880.

TRANSACTIONS.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

February 28, 1880 :—Messrs. W. P. Rice, Hosea Paul, S. J. Baker, C. A. Walter, A. Mordecai, J. Wainwright, G. Lindenthal, J. S. Oviatt, J. B. Davis and C. H. Burgess, met in County Surveyor's office, New Court House, and effected the first regular organization of the Civil Engineers of Cleveland. Committee appointed to prepare Constitution and By-Laws.

March 9, 1880 :—Constitution and By-Laws adopted, except as to name of organization. Nomination for permanent officers made.

March 13, 1880 :—Large accession of members. Name of "The Civil Engineers' Club of Cleveland" adopted. Officers elected: President, Charles Paine: Vice-President, A. Mordecai; Corresponding Secretary, W. P. Rice; Recording Secretary, C. H. Burgess; Treasurer, C. A. Walter. Committee on Library and Publication—H. Paul, M. E. Rawson, H. M. Clafton. Committee on Programme—G. A. Hyde, E. O. Schwägerl, Wm. Reuschel, A. M. Wellington, C. M. Baker.

March 27, 1880 :—Special Meeting at Board of Education Rooms. Public invited. Inaugural address by President Chas. Paine. Addresses by Col. J. M. Wilson, Col. Chas. Whittlesey, Hon. Geo. H. Ely, Prof. John White and Rev. J. W. Brown.

April 3, 1880 :—Resolution by W. P. Rice suggesting the joint publication of proceedings with other similar societies.

July 3, 1880 :—A. M. Wellington presented plan for joint publication. The matter referred to Committee on Publication and Library, with President Paine and Mr. Wellington.

January 8, 1881 :—Articles of "The Association of Engineering Societies" adopted. A. M. Wellington appointed member of Board of Managers. Resolutions of respect to the memory of Gen. Chas. B. Stuart, member, who died at Forest City House, Cleveland, January 4, 1881.

February 5 and 12, 1881 :—Committee to nominate officers and Committee on Programme for annual meeting appointed. Nominating Committee reported names of officers.

March 12, 1881 :—Annual meeting. Reports of officers read. Officers elected : President, Chas. Paine; Vice-President, Col. J. M. Wilson : Corresponding Secretary, M. E. Rawson ; Recording Secretary, C. H. Burgess ; Treasurer, C. A. Walter.

April 2, 1881 :—First meeting of club in new rooms in Case Library. President appointed Committee on Library and Publication, J. D. Crehore, J. F. Holloway, A. Mordecai ; Committee on Programme, M. W. Kingsley, C. M. Barber, H. M. Claflen, J. M. Richardson, E. O. Schwägerl; Member of Board of Management, M. E. Rawson. Resolutions of respect to the memory of C. A. Walter, Treasurer of the club, who died at McConnellsville, Pa., March 14, 1881. J. S. Oviatt elected Treasurer in place of C. A. Walter, deceased.

May 7, 1881 :—Time of meetings changed to second Tuesday evening of each month.

June 14 and July 12, 1881 :—Routine business. Papers and discussion. Adjournment to September 14, 1881.

INAUGURAL MEETING OF THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

Address by the President of the Club, Chas. Paine, Esq.

Gentlemen of the Civil Engineers' Club of Cleveland: I thank you for electing me President of this Club, thus associating me with the inauguration of a society which I have no doubt will be lasting, and of permanent benefit to its members and this community.

To all classes of men opportunities for social intercourse and for the exchange of ideas are a valuable means of improvement, but to persons engaged in scientific pursuits such occasions are of the greatest importance.

Before the two great Bacons, Francis and the Friar, the fathers of the philosophy of applied science, the boundaries of human knowledge were not so wide that one person, richly endowed, might not have traversed their entire circuit and have been familiar with all of the little which was then known of the positive sciences. At the present time, a familiarity with one little segment of the circle is all that a great student hopes to achieve. He may gaze with delight, during spare moments, at the surrounding firmament ; yet if he is a master of one science, we call him a master indeed. Yet the requirements of our profession are such that the Civil Engineer ought really to possess all knowledge ; which, being impossible, his next resource and best is to associate himself as intimately as possible with those informed in the branches of his art differing from his own, to be advised and instructed through their discussions, and obtain a many-sided view of things by the aid of other eyes, which observe from a different point of view. Recognizing the value of meetings for such professional discussions, the National Society, known as the American Society of Civil Engineers, was formed, with headquarters in New York ; and local clubs have been established in most of the large

cities of the United States. I congratulate you upon having founded this one in Cleveland, for there is no city in which a club of this kind has a better reason for existing, or in which we ought to expect more interesting proceedings or more useful discussions.

Let no member suppose, however, that the club will run of itself; on the contrary, in order to make it successful each one must bring of his best, and many willing members will have to do some good, hard work.

But they have already gained a broad and rich experience in their various callings, which has only to be narrated to make our meetings of the very highest interest; for experiment has shown in kindred societies that nothing provokes animated and wholesome discussion like a well-prepared paper.

There will be some members who will think that they have not time to write a paper; but it is a lack of industry rather than of time which prevents most persons from contributing to the papers of a society formed as this is—for mutual help.

There is occasionally one member found in such an association who suffers from modesty, thinking his words may not be of interest to the rest. To this rare fellow let me say, probably yours would be the best paper of the year.

You see that I take the privilege of a veteran to give advice, for being now stranded upon the very outer edge of the engineering profession, I can scarcely hope to make to you any other kind of communication.

Continuing, then, to advise, I urge you all to bring to the meetings all your experiences, discussions, discoveries, inventions, and mistakes; above all things, give the Club the advantage of your mistakes. All the great engineers say that they learned more from their mistakes than they did from their successes; and I think we would all agree that the most interesting parts of their writings are those which tell how they went wrong and how they got right. The papers of other engineering societies, here and abroad, are usually very frank in their statements and full in their account of the unfortunate experiences, as well as of the successes, of the writers, showing a very admirable desire to benefit all other members of their profession by teaching them how to avoid similar errors.

These professional papers taken together make up a body of information upon the most recent methods of working which far outweighs in value to the student of engineering the text-books of the schools, and I think the best graduates of those schools will be found to have got more knowledge from such society papers than from the professors. Of course I except from this sweeping assertion the professors of mathematics and chemistry, in whose hands are the keys of heaven and earth, by which the doors to all the halls of science are unlocked.

It seems to me, as I have hinted, that we are peculiarly well furnished here with materials for the most interesting studies, which I would not further allude to if we were not so apt to overlook things close at hand (our own, as it were) to contemplate great achievements in more distant regions.

In hydraulic engineering, for instance, our water-works embrace almost every very modern improvement or invention for supplying a great city with sweet water: a subaqueous tunnel; a crib exposed to the

storms of the lake; a reservoir; compound pumping engines, and a difficult distribution across deep valleys; so that if we were seeking for a compendium of what our art is ready to undertake in this department, we need not leave home to find it. The great iron and steel-works furnish excellent examples of the best use of high pressures for the movement of hydraulic cranes and similar appliances.

In these works may be seen also the most recent methods of steel making by the Bessemer and Siemens-Martin processes, the reduction of ores in modern, high, furnace stacks, and all the following steps from pig to bloom, from bloom to what you will.

At the wharves are new iron steamers with splendid engines. The arches of the viaduct are worthy of the best days of Rome, and its draw equals the best modern work in iron bridges.

In electric engineering we have the latest refinements, many of which originated here.

This Club should be the means of giving us more thorough knowledge of the details and peculiarities and problems presented by these works, and of the great number of other engineering works to which I cannot refer; and by the publication of deserving papers in the technical journals we ought to contribute our share to the instruction of those from whose similar efforts we learn so much.

In some of the largest cities it has been found convenient to separate the several more important departments of our profession into sections, forming societies of mechanical engineers, mining engineers, etc.; yet the leading members of these societies are members of the local civil engineers' clubs and of the American Society of Civil Engineers; and I hope we may unite in this Club all the energetic, studious, and earnest men of our profession, and of the allied professions who are living in this city or its vicinity, no matter to what specialty they may be devoted, The name taken by this Club will include them all.

Civil engineering, as defined by the charter of the British Institution, is "the art of converting the powers of nature to the service of man;" and we should invite and welcome to this Club any one who has taken for his pursuit in life any part in this wide ministry, whether as an inventor, chemist, master mechanic, contractor, or as a student of the exact sciences. The test should be: First, is the candidate an honorable man? Next, is he interested in the subjects which will be discussed? If he meets these requirements, the Club can only gain from admitting him; and it is to be hoped he may gain something also, for I think the advantages of a membership from a great variety of pursuits cannot fail to be of as much value to each member as to the Club collectively.

If the place where you meet and the personnel from which this Club is to be formed are fortunate, certainly I may add that the time is opportune.

Probably we look upon this age as more wonderful than it is, and are more rejoiced than we should be over the discoveries which are so often announced of the heretofore unknown and mysterious properties of matter; and we tremble, perhaps, at the fearful additions to the powers of man by which he has been advanced during the last few years, without good cause for alarm; and probably in future years, after

our children have become habituated to their use, as we have to the use of steam, they will see that it was only because we had been so ignorant that we were so surprised. Yet, with the liveliest anticipations of what revelations are in store for the prophets of nature, we can clearly see that the world has never before attained to anything like the knowledge of sciences and their application to the benefit of man, which has distinguished the nineteenth century beyond all others; so that, if a stimulant to debate is of use, it may be found in the news of the day, which heralds every morning a fresh discovery,

I know that there is an opinion, held by the worshippers of beauty (for whose pure thoughts and charming abstractions I would not seem to lack the sincerest respect), that these practical applications of science are not the highest, but rather the lowest, uses which can be made of the revelations of the divine laws; and these devotees appear to believe, indeed I doubt not they do truly believe, the condition of "the poor Indian, whose untutored mind sees God in clouds and hears Him in the wind," is in some respects better than that of the civilized creature who enjoys less of superstition but more of comfort.

We have set the romantic water-fall to grinding meal instead of making our squaws pound it with stones. We have even desecrated the plains of Greece, where once rose a glorious temple to Pallas Athene, by the erection of an ugly railway station. Bad as this is (and I would deplore the loss of any bit of beauty), it seems to me that the improvement of the race of men from primeval savagery to now has been due more to inventors than to any other class. As men have got better clothes, better food, better homes, they have become ready for higher ideas and better prepared for philosophical speculation. Experience has shown it to be dangerous for the missionary to approach the cannibal until his appetite for meat has been previously satisfied. If the Jesuit fathers, who sacrificed themselves in the first settlement of America with such generous intentions, had sought to teach the Canadian Indians the art of living more comfortably, the creed they brought would have recommended itself at first, as it has since, instead of seeming to the savage only an opposition religion.

I will not claim for our profession more than this: That it is the pioneer of spiritual progress; that the engineer prepares the world for healthful, convenient, happy living; drains the marshes, builds the highways, constructs the harbors, lays out the cities, supplies them with water, gas, drainage, telegraphs; and having rendered mankind as comfortable as he can he says to the spiritual guides, "The earth is the Lord's and the fullness thereof, and they that dwell therein. We have made the wilderness to blossom as the rose. Go ye now in and lead this people to a knowledge of the truth."

Mechanical engineering has set the forces of nature to do the worst drudgery that lay upon the shoulders of men, and it seems as if we can feel sure of the good time coming when no man shall do more hard work than is good for him, and all shall do as much; so that every man will have leisure to think of what concerns him more than material progress. But when that leisure is attained, and when the culture of his spiritual

and æsthetic inclinations shall be perfect and complete, he will owe those opportunities which he enjoys for such improvement to the antecedent labors of the Civil Engineers.

STREET PAVEMENTS.

BY E. O. SCHWÄGERL, MEMBER OF THE CLUB.

[Read August 7, 1881.]

There probably is no subject in civil engineering that has given the city engineer of every city more trouble and greater difficulties in surmounting many obstacles, such as unsatisfactory materials, dishonest contractors, unskilled labor, and lack of appliances and machinery; but a still greater difficulty everywhere arises, with either citizens or councilmen, who, from the nature of their position, are inspired with the conviction that they understand the subject fully and practically, and that civil engineers are purely theoretical men, without practical knowledge. Therefore, in preparing this paper our aim will be to avoid as much as possible technical words and expressions, leaving the exceedingly interesting and lengthy history and progress of pavements, omitting a statement of the great variety that has been tried, used and rejected, and confining these pages only to the more important practical interests relating to street pavements, aiming to reach the public as well as this Club.

The facts in this matter demand a careful consideration of the objects to be accomplished as well as the dangers to be avoided, of the several requirements of streets or roads according to their different use, of the suitable materials at command, and of the climatic influences to be overcome.

The qualities we should look for in a pavement are durability, the presenting of a desirable foothold to the horse's tread, and at the same time a smooth and easy rolling surface. The objects to be avoided are readily conceived by the opposite sense of those just stated. The evils to be avoided outnumber the desirable points to be attained, inasmuch as our streets and avenues are largely used in ways directly injurious to almost all pavements, viz., the infractions caused by street rails and the disturbances caused by pipe laying and repairing, all of which tend to disrupt the best of pavements. It is true that too little attention has been paid in this country in respect to selecting the right kind of pavement for the peculiar use or requirement of particular streets. For instance, we will classify streets under three heads : the pleasure road, the light traffic road, and the heavy traffic road. No road paved with heavy and hard material is conducive to pleasurable driving, while the streets or avenues used for pure pleasure driving are unsuited for heavy loads ; so that the one cannot assume to answer the purpose of the other, thus clearly implying that a discrimination should be made as to the use to which each street is most likely to be put.

It may be well to state now what we did intend to mention, in perhaps

a more suitable part of this paper, that certain streets should be restricted by law and regulation, specifying what kinds of vehicles should be allowed upon them: light traffic and pleasure roads should not be made thoroughfares for heavy loads, except as absolute necessity demands. A case in point: upon such a street as Euclid avenue, being in the highest sense of the word a light-traffic and pleasure road, market and all kinds of heavily laden wagons, should never be allowed to drive. These limitations should be enforced.

Casually glancing at the various pavements that have been in use in the United States, it is readily seen that experimenting, not by civil engineers, but by citizens and city officials, has been too common either for the benefit of the citizens or the credit of the civil engineers, to whom the faults of bad pavements are too frequently accredited. Furthermore, it is a lamentable fact that the engineer's opinion is too often cast aside, and some patentee's or contractor's untried notions adopted, at the expense of the tax-payers. We will not impute the thought that personal gain has been the object, but we do insist that the citizen, as well as the men who have by force of circumstances been placed in official positions—and consequently have been enabled directly or indirectly to dictate in matters pertaining to professional skill and learning—should be induced duly to respect the men who by their calling and life-work are best fitted to direct works of such magnitude and public importance, affecting the interests of the city and of every individual.

Relative to all kinds of street constructions and pavements a reform seems to be absolutely essential in the method and system of after keeping and care. Our pavements to-day are left and neglected until the entire street has become a wreck and unsafe for passage, until the citizens are disposed to make an entire renovation, or miserably patch up the work only to be again impassable in a short time. Street repairs should be made by a permanently organized corps of street repairers, employed by the city government, and whenever the pavement shows signs of weakness such points should at once be repaired. If an old and tried saying is true with relation to any fact, namely, "that a stich in time will save nine," the saying is most emphatically true as relates to pavements, for the disruption of a small portion of any pavement induces the constant continuance of that disruption, and also makes irregularities in the surface of the roads which directly or indirectly cause other breakages. Having thus barely hinted at facts that would admit of a great deal more amplification, but which for the present paper it seems advisable to omit, we treat the subject of pavements directly.

First, then, the various kinds of roadways of which we shall speak more especially are the earth and gravel drive-ways for light driving, the Macadam and its various modifications and substitutes for light traffic roads, and finally the pavements to be adopted for heavy traffic.

EARTH ROADS.

Earth roads, used only as pleasure drives or speeding ways, may be classified under two heads, those constructed upon sandy ground, and those upon clay ground. Roads composed of such light material do not admit of heavy or steep grades, as they will readily wash; neither should their grade be level, where the surface water will collect and make them

soft and muddy, besides disrupting the surface. The crowning of earth roads may vary from 1 to $1\frac{1}{2}$ inch to every 10 feet, rising from the gutter or sides to the centre or crown. When the soil is sandy the surface should be covered with a layer or thin course of hard-pan, clay, or shale, and rolled with an ordinary two-horse roller. An additional sprinkling of medium gravel adds to the permanency of such a road. On clay soil a coat of coarse sand or fine gravel, hard pan, or even shale is desirable. The principal matter with either of the above-named roads is their constant good care and attention, which, if conducted with the proper implements and intelligence, will secure the most pleasant, practical and economical drives, often sustaining a large and even heavy traffic. We beg leave to name the drives of Riverside Cemetery in this city, and also those of Gordon Park and our own race-course, as fair specimens of earth drives.

GRAVEL ROADS.

Gravel roads may properly follow in order, requiring an equal excavation of the road-bed, according to the amount of gravel to be replaced. Gravel roads have been built capable of sustaining the heaviest traffic, but it is a notable fact that gravel roads do not maintain their uniformity, nor wear so well as the more suitable pavements used for heavy traffic, strict and real economy ever pointing to a more extravagant first outlay.

LIGHT TRAFFIC ROADS.

The following pavements may be classified as coming under the head of light traffic roads: Macadam roads and their modifications, a large list of roads forming the basis of concrete and asphalt pavements, and leading also to the Telford system and its various modified forms.

A rule applicable to all pavements is to secure a road-bed that will not retain water, meaning more than mere drainage (which in itself should be perfect), but means a uniform compact surface of the road-bed precluded from becoming and remaining wet in spots, thereby creating sinkage and consequent breaking up of the road when in use. Therefore, in either forming or draining a road-bed the aim should be to produce a road-bed uniform in surface, compactness, and shape, and with an equally uniform and perfect drainage. When this is secured, with due care to retain these results during construction, much will have been done toward the perfect construction of a lasting road. In connection with the subject of needful and proper preparation for a lasting construction of any paved street is the matter of the displacement of sewers, gas and water pipes, which, as situated in all our cities, viz., directly under the road or street, can but be destructive to any system of pavement. The French system of constructing sewers large enough to contain these various pipes, and to admit of inspection, repairing, or making attachments, without disturbing the pavement, is as yet too extravagant in first cost to meet with general favor in our comparatively new country. It is to be regretted that so little effort, if any, is made to overcome this harmful and imperfect system. It is hoped that in this matter some genius among the thousands of civil engineers in the United States will devise a system that will disconnect the sewerage, gas and water pipes from interference with such an important feature of a city as the permanent pavement of its streets. It has often occurred to us that in the opening of new

streets the sewers and pipes might be located immediately under the sidewalk next to the curb or gutters, where the more perfect system of the French could not be introduced, and thus avoid the costly, inconvenient and destructive method of tearing up the pavement whenever repairs or additional connections are required.

The Macadam system is familiar to the members of this and similar clubs, yet the system is not so generally understood as to have induced its proper adoption. Many roads have been constructed with an ill-prepared and ill-shaped road-bed, upon which indifferently broken stones have been dumped and leveled, and have thus been left for use and termed Macadamized streets. Notably the city of St. Louis, having constructed miles of this so-called Macadam work, years after the loose stones would be rolled and kicked about, forming dangerous ridges alongside of the gutters and deep, muddy wheel-ruts in the centre. The popular aspect of such Macadamizing creates wrong and unjust impressions regarding one of the best and most economical systems of pavements.

The system requires, after the proper formation of the road-bed, curbing, and drainage, a course of the most suitable stone obtainable, from 6 to 8 inches in depth, broken into prismatic forms, the largest of which is capable of passing every way through a three-inch ring. It especially provides that foreign matter, such as earth, loam, clay, etc., should be strictly excluded. This course or layer should be rolled immediately after it has been watered, and while still wet, enabling the stones to be pressed beside one another by the roller, to form a solid and firm mass.

For rolling the Macadam a steam roller, weighing from 10 to 15 tons, should be applied. When this layer of broken stones has been evenly and smoothly rolled to a firm surface it is ready to receive the second or upper course, which will be from 3 to 4 inches in thickness. The stones for this second course should be broken so that the largest of them shall pass through a ring from 1½ to 2½ inches in diameter, placed so as to conform to the grade and crowning of the road, when it is ready to be treated as the first course, by watering and rolling, until a perfectly smooth, compact surface has been attained. Then it should receive a top dressing, of either fine stone chipped, or a moderately fine, sharp gravel, thoroughly watering the same so as to wash the particles within the joints, and it should again receive a thorough rolling. This process is not the original system of Macadam, as he is recorded to have compacted his roads only by means of the traffic of teams, and to have applied only one thick course of broken stones. But this system is that used by the French engineers for many years past, and by practical trial proved efficient and satisfactory, and has not without good cause credited France with possessing the finest Macadamized avenues in the world. We believe, however, that this world-wide reputation of the Macadam pavement, as constructed in France, is largely attributable, not only to the system or mode there prevailing, but to the excellent quality of stone with which they are made, viz., the fire-flint stone, of which they have inexhaustible quarries. This flint rock resembles somewhat a sponge, containing large openings or pores enabling it to be readily broken by hand to the desired size. Secondly, the manner of maintenance adopted

keeps them in perfect order. No abrasion of the Macadamizing is allowed to remain, but as soon as detected is carefully and thoroughly repaired, leaving not a trace visible to the eye that such work had been done. Notwithstanding the advantage of a superior quality of stone in France for this kind of pavement, our experience and observation favor this sized stone for Macadamizing in this country: First, because it is suitable, as much so as any system we know of, for the various qualities of stone which are at hand; and second, because if the broken stones be larger than 3 inches in diameter, and are not thoroughly bedded in a bed conforming to their shape, and are held in place by their sides with only a slight cavity under them, they will invariably be levered out of their position by the pressure and centrifugal motion of the passing wheels. The displacement of one such stone is rapidly followed by others, soon causing large infractions of the pavement. On the other hand, it is found that when the main body of the Macadamizing metal is composed of too small stones, they are easily displaced or torn out by the horses' hoofs. Hence, a size of stone must be selected that will thoroughly bed under the treatment, and firmly "mosaic" itself into a smooth, compact, and tenacious surface. Again, the metal should be free from foreign substances, especially in localities where frost is prevalent, and especially must it be free from substances similar to clay or vegetable matter, as such, when wet, cannot be considered as binding, but readily yields to pressure, inclining rather to assist the stones out of their position than to hold them, while frost acts more violently with such soils than with others less retentive of moisture.

With reference to road-rollers in connection with the means of packing loose stone roads, four systems have been employed, viz., the hand maul, now only applied in road repairs; wheel traffic, the horse-power roller, and lastly, the steam-roller, to which a fifth might be added, the steam rammers, which in some future day may prove very valuable. It seems, at this stage of intelligent road construction, almost superfluous to discuss at length the merits of these modes. However, as the advantage of a steam roller is so great, and yet so little appreciated, we deem it important herein to state briefly the more pointed advantages of this means of packing loose drive-way material. The traffic mode of making roads wastefully grinds the rock, unless covered with an undesirable quantity of binding material, besides requiring constant raking and shaping; involves greater and more serious loss by horse and vehicle wear than the cost of rolling by horse-power, eventually producing a very firm mass, yet such roads are never as smooth and regular, in consequence of more vegetable and other incongruous foreign matter becoming mixed with the surface rock, and are, consequently, more affected by the action of frost, requiring a long time ere the road-ways may be considered complete. The horse-roller system, though far preferable to the former, meets to some extent with several serious objections, one of which is that the horses' feet dislocate and distort the surface during the process, thereby permitting the mixture of foreign substances with the metal. The maximum weight attainable by horse-power is only two hundred pounds per square inch, and will only bind the softer rocks, unless aided by the application of binding material. The steam road-roller can be made to

apply any required weight to suit the materials at hand. The smooth shape of the metal surface remains undisturbed, except as pressed into permanent position, and the harder road metals are firmly compacted, admitting the use of hard binding materials. True, diversity of opinion prevails even among practical engineers in the use of rollers, but our own observation has been more favorable to the steam-roller than to the horse-roller, for performing better work, at less cost and in less time. With certain trap rock the steam-roller may create a so-called crust surface, especially when the watering of the metal during rolling does not penetrate below the surface course. We have found that the thorough packing of road metal depended as much upon thorough watering as upon the rolling. Hence, if the surface only is wet, the compression is perfect at the surface only, thus creating a so-called crust, with a loose and unsubstantial condition of the metal beneath, producing an unstable surface.

TELFORD ROADS.

The next system, which is an improvement upon the Macadam, is known as the Telford system. The Telford pavement, after a substantial road-bed and drainage have been established, provides a foundation of large stone from 3 to 6 inches in thickness, 8 to 10 inches in depth, and 6 to 16 inches in length, laid at right angles lengthwise to the line of the gutters, with their sharp sides upward, or the flat side down, set closely and breaking joints, after which the joints are filled with wedge-like pieces of rock and firmly rammed home with the hand-bar. This process requires fidelity of construction, filling all joints and hammering down all projecting points of stone, securing a finally uniform and even surface conforming to the grade and crown. The next following course should be from 3 to 5 inches deep, consisting of broken stone capable of passing through a two and a half inch or three-inch ring, treated like the lower course of Macadam, watered and rolled. This course is covered by another from 2 to 4 inches in thickness, reducing the size of the stone so as to pass in any direction through a ring from 1½ to 2 inches in diameter, again thoroughly watered and rolled.

We maintain that the metal should be practically clean, to secure a perfect bond. The final dressing should be clean and sharp, and may consist of either fine stone chips, coarse stone screenings, sharp gravel, or coarse sand, or even a mixture of the above, and applied to a thickness of from 1 to 2 inches, according to the joints left open by the last course. This dressing will also require a thorough watering to wash into and fill up all the minor joints, followed by thorough rolling.

The maintenance of either Macadam or Telford pavements we deem to be essentially or practically the same, viz., no breakage, however seemingly small, should be suffered without immediate repair, neither should its surface be allowed to accumulate mud, nor should the surface be allowed to become bare by high winds or heavy rains. An occasional sprinkling of coarse, sharp sand or very fine gravel will greatly increase the durability of its surface, and afford a much pleasanter drive-way. The comparison of the Telford system with that of Macadam, considering the substantial foundation of stone used, is largely in favor of the former. The laying of the foundation course with large stone and wedg-

ing costs considerably less than if the same quantity of stone were hand broken and compressed. The large stone used in the Telford forms a more permanent and firmer foundation than can be obtained with the lower stone course of the Macadam of equal thickness.

WOOD PAVEMENTS.

Wood pavements undoubtedly figure most prominently in the United States. That most common is the Nicholson, attracting the attention, not alone of civil engineers and contractors, but also of chemists and physicians. The most favorable features of the wooden pavements are notably their availability, their cheapness as compared with others, and the safe and cushioned foothold which they provide for the horses. Otherwise, it is not considered a salutary pavement, while its variable durability or indurability, even when chemically prepared, has placed it among the lower ranks of pavements, and to-day has given it a reputation in every city in the Union where tried, which will, in the future, largely exclude it. Yet its supporters, many of whom are men of the highest professional repute, and whose opinions cannot carelessly be disregarded, still claim that the wood pavements have not been fairly or efficiently tried. In this they are sustained by general experience. The wood used was invariably green or unseasoned, while its construction was often badly made.

The Nicholson pavement gave rise to many other, but similar, wood pavements, none of which have gained any special merit to our knowledge except that they have afforded practical observations and experiences from which we may gather some hints in the guidance of future developments. In the Western and Southern States cedar and cypress woods have been applied with considerable promise, at first; but so far as the test is observed, new conditions are developed which would prove them in no sense superior to the ordinary wood pavements. We do not think that wood as a pavement should be hastily rejected. The two first-named merits still bring it conspicuously before us, and should lead us to devise some developments, or some system that may yet prove a valuable factor in the perfecting of a pavement which is possessed of all the requisites necessary and desirable, and to which, if time will permit us, we will again refer.

CONCRETES.

A large class of pavements is included in the concretes and bitumens; these have been extensively used and tried, the latter having reached greater perfection in the milder climates of Europe.

Hydraulic cement concretes, 5 to 12 inches thick, have been generally adopted as most suitable for the base or foundations for bituminous road surfaces of whatever character, whether the cohesive substance used was coal-tar or asphaltum.

The bituminous pavements possess superior qualities to all others, being noiseless, impervious to water, elastic, clean, and agreeable in color to the eye, hence rightly claiming a large share of consideration. Their objectionable features are their smooth surface which, when moist, is very slippery, causing numerous accidents to horses; also their susceptibility to the extreme temperatures of our summers and winters, which to overcome is still a subject of study, experiment, and investigation among civil

engineers specially related to their construction. Thus far, even the best of this class of pavement has proven unsatisfactory in the United States requiring constant repairs if not entire renovation : by reason of these repairs they are not esteemed an economical pavement.

Coal-tar compounds are often destroyed during the process of preparation, if not by carelessness or indifference on the part of the contractor and workers. Asphalts are often ruined in a similar manner before being put down, hence the rapid and irregular disintegration of such roads, especially when subjected to extreme climatic tests.

A vital part in the construction of all compounded road materials before named is to have thoroughly qualified men in charge, who will properly and conscientiously prepare the material by exact proportion, careful mixing, and heating each mass equally to the required degree, avoiding burning. The good features or qualities of these pavements exceed their bad ones.

The cost of these pavements has been more variable and uncertain than the cost of others, having been subject to war fluctuation and importation. No reliable data can hence be found to be of any practical future importance.

STONE PAVEMENTS.

The older systems of pavement are undoubtedly the cobble stone and the stone block.

The cobble is still extensively used in smaller cities. This pavement is perhaps the cheapest among stone pavements, producing an exceedingly rough and unpleasant road, liable to shift in heavy grades. The displacement of one stone is easy, and this is soon followed by others, so that among stone pavements this requires frequent if not constant repairs.

The stone block system claims and deserves marked attention; though expensive in first cost, yet by its long duration and ease of maintenance, it can be esteemed as the cheapest. For heavy traffic it has no superior, if an equal, as it retains the original form of the road, is capable of being laid with uniformity and evenness, and of being relaid when called upon to endure sewer or pipe laying and repairing.

Its surface cannot be termed smooth nor comfortable, and certainly is the most harsh and hard, thereby causing perhaps not so many accidents as the smooth asphalt and concretes, but greater loss through the hard usage given to horses and great wear and breakage caused to vehicles. To what costly extent this waste of horseflesh and wagon may reach it is almost impossible to calculate. The larger size of the blocks, as formerly used, must indeed have increased this objection, as their slipping area was so much greater ; at present it is sought to make the blocks no wider than the calkings of the hoof can compass. The most perfect pavements of this kind we have ever seen were those laid upon the viaduct and the stone block pavement on Euclid avenue between Monumental square and Erie street this city, the latter having stood the test, with a constant heavy traffic for 16 years, without any practical repairing. Foundations for this pavement are variously made 6 to 12 inches in thickness, consisting either of hydraulic cement, concrete, Macadam well rolled, rubble stone, or a thick bed of gravel ; quite often of sharp, clean sand. The

blocks have been used of varying sizes; our choice of size would give them the following dimensions, $2\frac{1}{2}$ to $3\frac{1}{2}$ inches width, 7 to 12 inches length and 6 or 8 inches depth, set lengthwise, at right angles to the gutter line, breaking joints with each following course, the stones of each course selected to be of the same width or thickness, leaving no larger joints than $\frac{1}{2}$ inch, which are to be filled by either washing and sweeping into them fine, sharp gravel or coarse sand, then thoroughly hand rammed, or the joint may be filled with fine gravel and hot coal-tar or asphaltic cement. These imperfect observations regarding our standard pavements point to the material properties we should seek to obtain in devising any new pavement, which we will sum up as follows:

1. *Cheapness.* 2. *Durability.* 3. *Firmness of foothold to horses.* 4. *Smoothness.* 5. *Noiselessness.* 6. *Elasticity.* 7. *Cleanliness.* 8. *Imperviousness to water.* 9. *Agreeableness of color.*

Some of these properties are found in any of the pavements used, yet no one has them all, hence it becomes us to seek to accomplish so great a desideratum. One of the common errors which too often hinder the engineer is the influence that low figures have upon those controlling a work, which are regarded as the true index of cheapness, while the fact is lost that good material and good construction are the essential elements in any kind of pavement, and such cannot be obtained without fair and just compensation. This has been frequently illustrated in every city, under the baneful and unjust system which gives the work to the one who, either through ignorance or willful purpose, makes bids for material and work so low as to drive competent and honest contractors and laborers out of the field of fair competition.

It has often seemed to us that material and labor—admitting to be measured and an honorable living price adjusted—should be controlled by a contraction and maintenance department, supervised by the Engineer in Chief, whose position and profession demand knowledge, training, skill, experience and honesty, and that he and his corps should be the proper persons held responsible. Such a system would enable a fairer distribution of work among the tax-paying citizens, while such a department would be enabled to select its own material and give to it the needful treatment or seasoning before use, and finally insure a construction that will yield all that can be required of it, according to its kind and cost.

We desire to lay before this Association a system of pavement which has long been entertained by us, never having met with it and never having had the occasion to apply it to any works under our direction. For all roads we advocate a firm, solid, well-shaped road-bed, and desire efficient drainage, upon which bed we would place rubble stone 12 inches in depth in the centre and 8 inches in depth next to curb-stones; the stones may be irregular; length, 8 to 16 inches; depth, 6 to 10; width, 3 to 8 inches, approximately. Set these stones lengthwise at right angles to the gutter line, broadest side down; afterward place another course of smaller and wedge-shaped stones within all open joints, spay side down, and firmly ram them by hand-bar and break off all points projecting above grade or crown. This surface is then to be covered with a coat 2 inches thick of either coarse

gravel, or fine broken stone, or chip stone ; water and roll the same. This foundation to constitute the pavement proper, upon which may be placed either a sprinkling of medium gravel, or even coal tar and sand, then add any surface wearing material, either of wood, stone, or concrete ; our first preference would be the application of the Nicholson system ; however, reducing the width of the blocks one-fourth of an inch, the wood to be thoroughly seasoned and creosoted, compactly filling the joints above the strips with gravel and coal-tar, and a final filling of asphaltic cement. The object of this pavement is ostensibly to obtain an indestructible foundation, and replacing only the wearing surface, the future expense of which would be comparatively light. Besides this mode would readily admit the easy replacement of its foundation and surface when necessarily removed to allow underground work on sewers, gas or water pipes without creating irreparable harm to the pavement or shape and smoothness of the road. The pavement next to the car tracks should be of stone blocks, with alternately long and short blocks laid at right angles to the track. With reference to pavements next to car tracks except stone blocks, much danger and many accidents are incurred, besides the unreasonable wear upon vehicles caused by the invariable deep ruts there found, and consequent disruption of the pavement itself.

We also venture to suggest, in order that future data of value may be easily obtained, correct data to be gathered with reference to every properly constructed pavement, giving date, kind of material, its cost and construction, repairs and maintenance, and duration of each kind. From such data a tabular statement could be made, giving the exact proportional value of each pavement for the same period of time. The effect of pavements upon horses and vehicles, as also their sanitary character, might be more attainable by such statistical items. Such tables have been in a small degree attempted ; but this work requires a general interest by all the city departments of our cities.

We now leave this subject in your hands, in the hope that we have, at least in a slight degree, recalled facts which, though not new to you, every member may newly apply himself to the discovery or devising of better systems of street pavement, aiming to reduce first cost and secure lasting and humane ends to both man and beast, with credit and honor to the calling and profession which we represent.

PROCEEDINGS.

September 14, 1881 :—A regular meeting of the Civil Engineers' Club of Cleveland was held at its rooms.

Meeting called to order, Vice-President Col. J. M. Wilson in the chair. Minutes of July meeting read and approved. No meeting held in August.

Mr. Charles Paine tendered his resignation as President of the Club, having accepted an important position upon an Eastern railway necessitating his removal from the city. Mr. Paine's resignation was accepted with many regrets by the Club, as he has been its President from the first, its success being largely due to his wise counsels and his many donations of books, reports, etc. Mr. Paine has the assurance that the best wishes of the Club will attend him in his new field of professional labor. On motion, a committee was appointed, consisting of Vice-

President Wilson, Rev. J. W. Brown, B. F. Morse. J. D. Crehore and Charles Latimer, to prepare and present proper resolutions upon the subject.

On motion, Mr. Edward Lindsley was elected to active membership, and Prof. J. N. Stockwell, of Cleveland, to the first honorary membership in the Club. It desired to acknowledge thus publicly his personal worth and scholarly attainments, and more especially his valuable contributions to the field of astronomical science, which have been recognized and accepted as authority in this country and in Europe.

On motion, the sum of $100 was appropriated to be used for the purpose of joint publication. The number of copies of the first issue of the publication to be taken by the Club was, on motion, left to M. E. Rawson, member of the Joint Board, to decide.

Mr. H. C. Thompson (Mem.), Assistant Engineer on the N. Y., P. & O. Railway, gave the Club a most interesting detailed description of the simultaneous narrowing of the gauge upon 240 miles of main and side track on the line of that road, accomplished on the 22d of June, 1880, in about six hours' time. Mr. Thompson's remarks were interspersed with a large number of blackboard drawings of the complicated frog angles, switch bars, etc., and of the multitude of gauge bars, spotting bars, etc. Mr. Thompson also described the process of "third railing" a portion of their road, accomplished while all trains were running.

This feat, showing the marked progress in modern railway engineering, deserves permanent record, and it is hoped that Mr. Thompson will embody his remarks upon paper, with proper drawings, for printing with the papers of the Club.

On motion, a vote of thanks was tendered Mr. Charles Paine for a further donation of books and papers.

On motion, Messrs. S. J. Baker and W. P. Rice were appointed a committee on the preparation and rearrangement of the Club Reading Room upon nights of meeting.

On motion, the Club adjourned to meet on the second Tuesday evening in October.

M. E. Rawson, Secretary.

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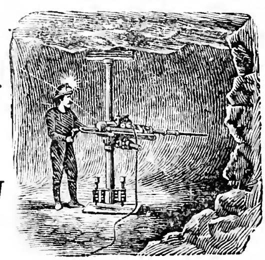

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ORGANIZED 1848.

TRANSACTIONS.

This Society is not responsible as a body for the statements and opinions advanced in any of its publications.

WATER-LIFTER AT BOISE CITY, IDAHO.

BY THOMAS DOANE, PRESIDENT OF THE SOCIETY.

[Read September 21, 1881.]

A little more than two years ago, while making a six days' trip by stage, I stopped off on Saturday noon at Boisé City, Idaho, for a days' rest. While looking the city over in the afternoon, I became much interested in its irrigating works, and made some examinations and measurements, the notes of which I have carried in my pocket ever since, not having had an opportunity to prepare them in a suitable manner to lay before the members of our Society. Some of the members may perhaps be familiar with the process, but to most of them the process there in use for lifting water will be new.

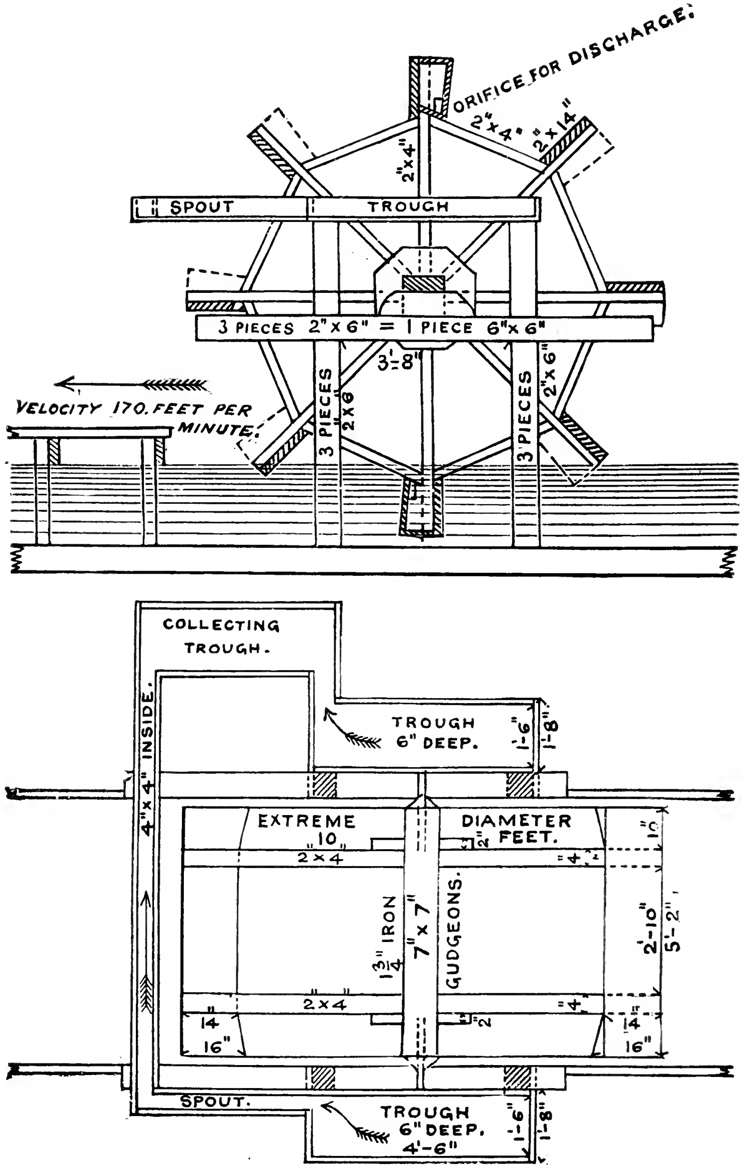
Boisé City is situated upon the bottom lands of Boisé River Valley, and the town site is very flat. The soil is a very free and in most places very coarse gravel at a little distance below the surface.

For want of rain no vegetation can grow except sage brush, which readily retires when water in any appreciable quantity is provided.

The town is laid out in rectangular form as to its streets and area. The waters of the Boisé River have in part been turned into a large ditch a few miles above the city and brought in ditches where the ground is high enough, and in flumes and tubes across low places, to the city. Here it is divided and carried in smaller ditches and flumes down several of the more important streets, which have the necessary fall, and through the town. The water is carried at one side only of a street, and between the driveway and the sidewalk.

The water on lands high enough to be suitable for business or residences is in a ditch, and must in some way be lifted in order to be available for watering the gardens or carrying it to the houses.

The people have adopted for this work a water-wheel with blades dipping into the water of the ditch, by which it is revolved. To the arms of the wheel little buckets are attached, which are filled when the wheel



WATER-LIFTER AT BOISE CITY, IDAHO.

Circumference at centre of blade = 27.72 ft.; velocity of water in flume = 170 ft. per min.; revolutions = 5½ per min.: velocity of centre of blade = 152.46 ft. per min. Sixteen buckets, each 1.1 × 0.7 × 0.7 = 0.539 cub. ft. Efficiency (about ⅔) = ⅓ cub. ft. Lift, about 5 ft.

dips into the water, and discharged into troughs at the side of the wheels after being elevated a few feet.

I have prepared and furnish herewith a few diagrams of a wheel which I measured as being one of about average size. Wherever a water-lifter is to be placed the ditch must have a flume built in it with flat bottom and vertical sides. Upon the sides of the flume a frame is erected to carry a wheel. The wheel measured had an extreme diameter of 10 feet, with blades 5 feet 2 inches long and 14 inches wide. It had eight arms set on a 7×7 inch square shaft, with gudgeons of $1\frac{3}{4}$ iron. Each end of each arm or blade is provided with a little wooden bucket of a capacity when full of about one-half a cubic foot.

The construction of the machine can probably be easily understood from the diagrams. It is roughly and cheaply made, but its friction is very small and it does very efficient work. The buckets are not tight and are discharging more or less water on their way up from the flume.

The velocity of water in the ditch was 170 feet per minute. The wheel made $5\frac{1}{2}$ revolutions per minute. The circumference of the wheel at middle of blades was 27.72 feet and its velocity 152.46 feet per minute.

It carried up 16 buckets of water at each revolution, or 88 buckets per minute, equal to 44 cubic feet of water at one-half cubic foot per bucket. I have upon the diagram indicated an efficiency of two-thirds, which would yield $29\frac{1}{3}$ cubic feet. This is very likely much too large in the case of fixed buckets, which are discharging part of their contents all the way up. The bottoms of these buckets, or that part which becomes a bottom at the upper part of the revolution, are so inclined as to project the water into the troughs at the sides through some small orifices in the outer ends of the buckets. This will be seen from the diagram.

In other cases tin buckets are suspended on pins, so as to carry all their contents to the top of the revolution, when they are tipped and discharged by being carried over a pin. As will be seen from the near approach of the velocity of the wheel blades to the velocity of the water of the ditch these water-lifters are very efficient and cheap machines. After the water is lifted into the troughs, it is carried into the yards or houses by spouts set upon fences or movable horses, or by hose. To carry the water across streets, it is necessary to lay logs beneath the roadway, and lift it into troughs upon the other side, or connect with hose. I noticed one wheel in the town which had become crippled by the loss of a single blade, and it was interesting to watch its work. It made a part of its revolution at normal speed, nearly, but when the arms without a blade entered the water, it found itself powerless to lift all the water it had bargained to do, and gradually came to a standstill. Then the *leaky* buckets came to its aid by discharging their water slowly, until the current's force upon the naked arms of the defective member, and upon so much of the adjacent blades as were in the water, restored it to life and action. There was a case in which a defect in a second member came to the rescue of another defective member, and gave the machine a proportion of its efficiency, which it could not have had if the buckets had been tight.

Several neighbors on the same or both sides of a street generally unite in putting up a wheel, and use the water jointly. It is usually kept run-

ning all through the day and evening, and makes the vegetation very green.

One of the citizens remarked that with so much water and such a porous soil, other wheels were wanted to furnish liquid manure.

The wheels while in operation gave a delightful coolness to the surrounding air. If they were properly provided with trellises and vines, very pleasant and beautiful arbors might be secured.

NOTES AND COMMUNICATIONS.

Estimation of Distances by the Time Consumed in Horseback Riding.

Submitted by Mr. C. W. Folsom.
[November 16, 1881.]

It is often desirable, in a new country, when exploring routes whose lengths are not known, or cannot be learned from reliable sources, to have some standard for *estimating distances.* And the mode most in vogue and most easily practiced is to estimate the distance from the time occupied in traveling, usually on horseback.

During the last spring and summer several opportunities have been afforded upon this road to Mr. Doane, the Chief Engineer and myself of testing the reliability of this method.

In the month of March, 1881, Mr. Doane made a reconnoissance of the whole line of the proposed Atlantic & Ohio R. R., from the Valley of Virginia to Charleston, West Virginia: computing the distances traveled by the time taken in riding, and allowing various rates of speed, from $2\frac{4}{10}$ to $4\frac{2}{10}$ miles per hour. For the portion referred to in this paper, however, a uniform rate of $3\frac{6}{10}$ miles per hour was used, the convenience of assuming that exact fractional rate rather than $3\frac{1}{2}$ miles being that it is only necessary to multiply the minutes of the time spent in riding by the even decimal 0.06 in order to give miles: and as it was desirable not to underrate the distance in estimating the cost, it was supposed that that would be at least a large enough allowance in this particular place, as it was.

On subsequently comparing the measured line near here with the estimated distances, we found that Mr. Doane's estimates on this particular section overran by about $7\frac{1}{2}$ per cent.; that is, one should deduct $7\frac{1}{2}$ per cent. from the distance estimated by a rate of riding of $3\frac{6}{10}$ miles per hour in order to get the correct distance.

It should be said, in this connection, that the riding was along a fairly-built bridle-path, on the bank of the lower part of the Elk River. On this, however, there were numerous small détours, made in crossing creeks, etc.; so that the actual distance traversed by the horse was somewhat greater than the length of the railroad line surveyed.

Of course the rate of riding varies with the character of the horse, of the rider, and of the road; but the reconnoissance of a railroad route in the more thinly settled sections of the country will not afford much room for differences from either of these causes.

I annex some records of rides actually taken, both by Mr. Doane and

by myself; with the miles as afterwards measured, and the decimal of "miles to a minute," resulting from each ride.

It is proper to note that Mr. Doane's rides were part of a steady journey in company with two other riders (in which way horses and men generally travel faster); whereas my own were more leisurely rides, taken alone, with short stops to note courses, etc.

Mr. Doane rode:

March 24....	14.05 miles in	225 minutes, or	.062 miles per minute.
March 25....	20.01 miles in	400 minutes, or	.050 miles per minute.
Total.....	34.06 miles in	625 minutes, or	.054 miles per minute.

or about $3\frac{1}{4}$ miles per hour.

Mr. Folsom rode:

Sept. 29...	3.36 miles in	70 minutes (both going and returning) or	.048 miles per min.
Sept. 29...	4.40 miles in	90 minutes.......................... or	.049 miles per min.
Sept. 29...	10.57 miles in	255 minutes (going)...................... or	.041 miles per min.
Sept. 29...	10.57 miles in	220 minutes (returning)................ or	.048 miles per min.
Oct. 7.....	4.42 miles in	80 minutes............................... or	.055 miles per min.
Oct. 7.....	2.40 miles in	55 minutes............................... or	.044 miles per min.
Oct. 15.....	6.92 miles in	146 minutes............................. or	.047 miles per min.
Total...	42.64 miles in	916 minutes............................. or	.046 miles per min.

or about $2\frac{3}{4}$ miles per hour.

Average of Mr. Doane's and Mr. Folsom's taken together, 76.70 miles in 1,541 minutes, or nearly .05 miles per minute, or an average speed of 3 miles per hour.

PROCEEDINGS.

NOVEMBER 16, 1881:—A regular meeting of the Society was held at 7:30 P. M. President Doane in the chair and thirteen members present.

The record of the last meeting was read and approved.

The election of Librarian and filling the vacancies on the committees on Metric System and on Class-List of Engineering Books in the Public Library were postponed for one month.

The Secretary was authorized to have the copies of the Proceedings now on hand bound in pamphlet form.

Prof. George L. Vose was elected a member of the Society.

Mr. George T. Sampson read an account of the construction of the Whalley Pond Trestle on the extension of the New York & New England Railroad.

President Doane described a pile bridge for winter use, built by him on the line of the Northern Pacific Railroad, across the Missouri River at Bismarck, Dakota.

Mr. L. F. Rice exhibited a profile showing the result of some observations made by him in 1871 on the fluctuation of the water in the stand-pipe of the St. Louis Water-works.

[*Adjourned.*] S. E. TINKHAM, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

ORGANIZED 1868.

TRANSACTIONS.

TABLES FOR DETERMINING THE PROPER SIZES OF SEWERS.

By Robert Moore, Member of the Society.

[Read November 10, 1880.]

The tables which I lay before you this evening were constructed for use in the Sewer Department of this city, and have been found to be in practice of so much convenience and value that I have thought them worthy of presentation to the club.

The purpose of them all is to answer the question which in planning sewers arises more frequently than any other, viz., what size must a sewer with a given grade have in order to discharge a given amount of water?

The first and largest table gives the diameters of circular sewers with various inclinations capable of discharging one inch of rain per hour from any given number of acres, from one up to one thousand, the depth of the water to be at no time over three-fourths the diameter. This is the table in accordance with which the greater part of the sewers in St. Louis are laid out, they being intended mainly and almost without exception for the carriage of storm water.

The second table gives the sizes of sewers intended for the drainage of single lots. As sewers of this class take the water from roofs, which gets into them very rapidly, this table gives the sizes necessary to discharge 2 inches of rain per hour, or double that of the former table.

Notwithstanding their great capacity, the sizes given in this table are very much less than were commonly used for this purpose heretofore.

The largest size in the table is $8\frac{3}{4}$ inches, which is equal to the drainage of a lot 150 by 200 feet, with a fall of only 1 foot per 100. But a few years ago, when the Sewer Department was allowed no voice in the matter, it was common to put in a 12 or even a 15 inch pipe for the drainage of a single house on a 20 or 25 foot lot. And nothing is more difficult than to convince persons accustomed to this practice that these sizes are not necessary. They resist any reduction of size with a tenacity that is almost incredible. But when the small pipes are once in nothing further is ever heard from them.

This table, as well as the first one, gives also the velocity of the water at the time of its greatest depth, a thing which it is often very necessary

to know. For if the velocity is too little, say less than 3 feet per second, the sewer will not keep itself clean; while if it is too great, say over 15 feet per second, there is danger of washing out the cement and loosening the brick-work, this being in fact something of frequent occurrence in the sewers of this city.

The third table gives the proper sizes of a class of sewers hardly yet known in St. Louis, viz., sewers intended to receive house drainage only, to the exclusion of storm water. This table is based upon the measurements of the sewage, or dry weather flow, in the Compton avenue sewer made last spring and reported already to the Club by Mr. Moulton, and the sizes of the pipes indicated by it are sufficient to discharge in 24 hours 1,250 gallons per house, or 50 gallons per front foot from the whole district to be drained. This is about 50 per cent. more that the maximum discharge found in the Compton avenue sewer.

Here again, with a large excess of capacity, we have sizes which look surprisingly small. For example, a pipe of only seventeen-hundreths of a foot, or about 2 inches, diameter, with a fall of 1 foot per hundred, is shown to be equal to the drainage of 20 houses, or 500 front feet. In actual practice, of course, no one would ever lay down a pipe so small as this, 6 inches being, I think, the least size of pipe that should be laid for the drainage of more than one house. That part of the table giving sizes below this has, therefore, only a theoretical value.

The formulas upon which the tables are constructed are found as follows:

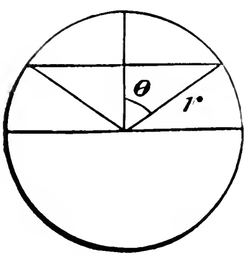
First, it is necessary to find the velocity of the flow in a circular sewer of given diameter and fall when running three-fourths full.

The generally received formula for the flow of water in open channels, as given by Weisbach (Vol. I., American edition, page 965) is:

$$v = \left(\frac{F}{p} \cdot \frac{h}{l} \cdot \frac{2g}{\zeta} \right)^{\frac{1}{2}}$$

in which

v = The mean velocity in feet per second after the motion has become uniform.
F = The area of the cross section of water.
p = The wetted perimeter.
h = The fall of the sewer in the distance l.
g = The acceleration of gravity.
ζ = An experimental coefficient of friction whose value varies with the velocity and with the smoothness or roughness of the walls of the conduit.



To adapt this to the particular case of a circular conduit three-fourths full we must find the value of $\frac{F}{p}$, or the hydraulic mean depth, in terms of the diameter d.

To do this let θ (see figure) be the half arc of the empty segment for radius unity, and let r be the radius of the given circle. Then will the area of the empty segment be:

$$r^2 \theta - r^2 \sin. \theta \cos. \theta, \text{ and}$$

$$F = \text{area whole circle—empty segment} = \pi r^2 - r^2 \theta + r^2 \sin. \theta \cos. \theta,$$

and,

$$p = \text{circumference—arc of empty segment} = 2\pi r - 2r\theta.$$

Therefore,

$$\frac{F}{p} = \text{mean depth} = \frac{r}{2} \cdot \frac{\pi - \theta + \sin.\theta \cos.\theta}{\pi - \theta} = \frac{d}{4}\left(1 + \frac{\sin.\theta \cos.\theta}{\pi - \theta}\right)$$

For the particular case of a sewer three-fourths full

$$\theta = \text{arc } 60 = \frac{\pi}{3}$$

$$\text{and } \frac{F}{p} = 0.3017\, d.$$

For the sewer entirely full

$$\theta = 0 \qquad \sin.\theta = 0$$

$$\text{and } \frac{F}{p} = 0.25\, d.$$

Showing that the hydraulic mean depth and the velocity of the flow is less when the sewer is full than when it is three-fourths full. The maximum velocity occurs when the angle θ is about 50 degrees.

Introducing the value of $\frac{F}{p}$ as thus found (for $\theta = 60°$) into the general formula for velocity it becomes

$$v = \left(0.3017\, d\, \frac{h}{l}\, \frac{2g}{\zeta}\right)^{\frac{1}{2}}$$

If now we put l = 100 feet and h = the fall per 100 feet and give to g its ordinary value of 32.2, this formula becomes:

$$v = \left(0.19429\, \frac{hd}{\zeta}\right)^{\frac{1}{2}}$$

And if, still further, we give to ζ the value 0.00769, which Weisbach (p. 967) gives it for a velocity of 5 feet per second, we get:

$$v = 5.0264\, (hd)^{\frac{1}{2}}$$

Second. We come now to the main problem, viz., to determine the diameter of a sewer of proper size to drain a given area, the grade of the sewer and the amount of rainfall to be discharged being also given.

To obtain this we have first of all the general relation

$$Q = Fv.$$

in which

Q = The quantity of water to be discharged in cubic feet per second.
F = The area of the cross section of water, and
v = The mean velocity in feet per second.

If the quantity to be discharged be taken as b inches of rain-fall on n acres we shall find that

$$Q = b\, n \text{ cubic feet per second very nearly}$$

We then have

$$Q = b\, n = F\, v.$$

Using the values of F and v just found we get

$$b\, n = \frac{d^2}{4}(\pi - \theta + \sin.\theta \cos.\theta)\left(\frac{d}{4}\, \frac{\pi - \theta + \sin.\theta \cos.\theta}{\pi - \theta}\, \frac{h}{l}\, \frac{2g}{\zeta}\right)^{\frac{1}{2}}$$

$$= \left(\frac{d^5}{64}\, \frac{(\pi - \theta + \sin.\theta \cos.\theta)^3}{(\pi - \theta)}\, \frac{h}{l}\, \frac{2g}{\zeta}\right)^{\frac{1}{2}}$$

Squaring
$$b^2\,n^2 = \frac{d^5}{64}\,\frac{(\pi - \theta + \sin.\,\theta \cos.\,\theta)^3}{(\pi - \theta)}\,\frac{h\,2g.}{l\ \zeta}$$

$$d^5 = \frac{64\,b^2\,n^2\,l\,\zeta}{h\,2\,g}\,\frac{(\pi - \theta)}{(\pi - \theta + \sin.\,\theta \cos.\,\theta)^2}$$

$$d = \left\{\frac{64\,b^2\,n^2\,l\,\zeta}{2\,g\,h}\,\frac{(\pi - \theta)}{(\pi - \theta + \sin.\,\theta \cos.\,\theta)^3}\right\}^{\frac{1}{5}}$$

If we put $l = 100$, $\zeta = .00769$ and $\theta =$ arc 60°, this becomes

(1) $$d = \left\{\frac{b^2\,n^2}{10h}\right\}^{\frac{1}{5}} = \left\{\frac{Q^2}{10h}\right\}^{\frac{1}{5}}$$ in which

q = Quantity, or cubic feet per second, discharged.
b = Number of inches of rainfall per hour to be discharged.
n = Number of acres to be drained.
h = Fall of the sewer per 100 feet, and
d = Diameter in feet of the sewer required.

By giving to b in this formula various values we get the following:

(2) $b = \frac{1}{2}$ inch per hour.................... $d = \left\{\frac{1}{4}\,\frac{n^2}{10h}\right\}^{\frac{1}{5}}$

(3) $b = \frac{3}{4}$ " " .... $d = \left\{\frac{9}{16}\,\frac{n^2}{10h}\right\}^{\frac{1}{5}}$

(4) $b = 1$ " " .... $d = \left\{\frac{1}{1}\,\frac{n^2}{10h}\right\}^{\frac{1}{5}}$

(5) $b = 2$ " " .... $d = \left\{4\,\frac{n^2}{10h}\right\}^{\frac{1}{5}}$

and so on.

In calculating table No. 1 formula (4) was used. Table No. 2 was calculated by formula (5).

In order to calculate table No. 3 the notation of formula (1) was modified so that

n = Number of front feet drained.
b = Number of cubic feet per second discharged from each front foot.

Taking b as 50 gallons per front foot per day, or $\frac{6,684}{86,400}$ cubic feet per second, and reducing we get

$$d = \frac{1}{70}\left\{\frac{n^2}{h}\right\}^{\frac{1}{5}}$$

which was the formula actually used.

It should be noted that in calculating these tables the coefficient of friction was, for convenience, treated as though it were a constant, but one value of it being used for all velocities. As a matter of fact, however, it is not constant but changes slightly with the velocity, its value decreasing as the velocity increases. Its values for different velocities, as given by Weisbach, are shown in the following table:

VELOCITY IN FEET PER SECOND.	ζ	Logarithms.
0.5	0.01025	8.0107239
1................	0.00883	7.9459607
2	0.00812	7.9095560
3	0.00788	7.8965262
5	0.00769	7.8859263
7	0.00761	7.8813847
10	0.00755	7.8780045
15	0.00750	7.8752928

If very great accuracy is required the diameter, as shown in the tables,

TABLE NO. II.

Table of Diameters of House-drains with various Grades and for Lots of different sizes, capable of discharging 2 inches of rain per hour when running three-fourths full.

Dimensions of Lot.	Number of acres.		Fall, 1 per 100.	Fall, 1½ p'r 100.	Fall, 2 per 100.	Fall, 2½ p'r 100.	Fall, 3 per 100.	Fall, 4 per 100.	Fall, 5 per 100.
		Velocity.......	2.69	3.16	3.54	3.87	4.17	4.68	5.11
20 × 150	0.0689	Diam., feet....	.286	.263	.249	.238	.229	.216	.207
		" inches..	3½	3⅛	3	2⅞	2¾	2⅝	2½
		Velocity.......	2.81	3.30	3.71	4.05	4.36	4.89	5.35
25 × 150	0.0861	Diam., feet...	.312	.288	.272	.260	.251	.237	.226
		" inches..	3¾	3½	3¼	3⅛	3	2⅞	2¾
		Velocity.......	2.91	3.43	3.84	4.20	4.52	5.07	5.54
30 × 150	0.1033	Diam., feet....	.336	.310	.292	.280	.270	.254	.243
		" inches..	4	3¾	3½	3⅜	3¼	3	3
		Velocity.......	3.00	3.53	3.96	4.33	4.66	5.23	5.72
35 × 150	0.1205	Diam., feet...	.357	.329	.311	.297	.287	.271	.259
		" inches..	4¼	4	3¾	3⅝	3½	3¼	3⅛
		Velocity.......	3.09	3.59	4.07	4.45	4.79	5.37	5.87
40 × 150	0.1377	Diam., feet....	.377	.347	.328	.314	.302	.286	.273
		" inches..	4½	4¼	3⅞	3¾	3⅝	3½	3¼
		Velocity......	3.16	3.71	4.17	4.56	4.90	5.45	6.01
45 × 150	0.1550	Diam., feet....	.395	.364	.344	.329	.317	.299	.286
		" inches..	4¾	4⅜	4⅛	4	3⅞	3⅝	3½
		Velocity.......	3.23	3.79	4.26	4.65	5.01	5.62	6.14
50 × 150	0.1722	Diam., feet....	.412	.380	.359	.343	.331	.312	.299
		" inches..	5	4½	4¼	4⅛	4	3¾	3⅝
		Velocity.......	3.35	3.93	4.41	4.88	5.19	5.83	6.37
60 × 150	0.2066	Diam., feet....	.443	.409	.386	.369	.356	.336	.321
		" inches..	5⅜	4⅞	4⅝	4⅜	4¼	4	3⅞
		Velocity......	3.45	4.06	4.55	4.98	5.35	6.01	6.57
70 × 150	0.2410	Diam., feet....	.471	.435	.410	.392	.378	.357	.342
		" inches..	5⅝	5¼	4⅞	4¾	4½	4¼	4⅛
		Velocity......	3.54	4.17	4.68	5.11	5.50	6.17	6.75
80 × 150	0.2755	Diam., feet ...	.497	.458	.433	.414	.399	.378	.360
		" inches..	6	5½	5¼	5	4⅞	4½	4⅜
		Velocity.......	3.63	4.27	4.79	5.23	5.63	6.32	6.91
90 × 150	0.3099	Diam., feet....	.521	.480	4.54	.434	.418	.395	.378
		" inches..	6¼	5¾	5½	5¼	5	4¾	4½
		Velocity......	3.71	4.36	4.89	5.35	5.75	6.45	7.05
100 × 150	0.3443	Diam., feet....	.544	.501	.473	.453	4.36	.412	.394
		" inches..	6½	6	5¾	5½	5¼	5	4¾
		Velocity.......	3.87	4.56	5.11	5.59	6.01	6.75	7.38
125 × 150	0.4304	Diam., feet....	.594	.548	.517	.495	.477	.450	.431
		" inches..	7⅛	6½	6¼	6	5¾	5⅜	5⅛
		Velocity.......	4.02	4.73	5.30	5.80	6.24	7.00	7.65
150 × 150	0.5165	Diam., feet....	.639	.589	.556	.532	.513	.484	.463
		" inches..	7⅝	7⅛	6⅝	6⅜	6⅛	5⅞	5⅝
		Velocity.......	4.14	4.87	5.47	5.99	6.45	7.22	7.89
175 × 150	0.6026	Diam., feet....	.680	.627	.592	.569	.546	.515	.493
		" inches .	8⅛	7½	7⅛	6⅞	6½	6¼	6
		Velocity......	4.26	5.06	5.62	6.14	6.61	7.41	8.10
200 × 150	0.6887	Diam., feet....	.717	.661	.624	.597	.576	.544	.520
		" inches..	8⅝	8	7½	7⅛	6⅞	6½	6¼

may be recalculated with the coefficient ζ corrected for the velocity of the particular case. In most cases the error is very small. For example, the correction for a sewer draining 1,000 acres with a grade of eighty-five-hundredths of a foot per 100 feet and a velocity of 15 feet per second is only five-hundredths of a foot in a diameter of 10.26 feet, or half of one per cent. As this is an extreme case it shows that for ordinary cases the errors of the table, due to this cause, are so small that in practice they may be disregarded.

TABLE NO. III.

Diameters of Sewers capable of discharging 50 gallons per front foot, or 1,250 gallons per house (25 front feet) per day when running three-fourths full.

Number front feet.	.2	.4	.6	.8	1.0	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00	No. of houses..
	Fall of sewer per 100 feet.																	
	Diameter in feet.																	
100	.124	.108	.100	.094	.090	.086	.083	.081	.078	.077	.075	.074	.072	.071	.070	.069	.068	4
200	.164	.143	.132	.124	.119	.114	.110	.106	.103	.101	.099	.097	.095	.094	.093	.091	.090	8
300	.193	.168	.155	.146	.140	.134	.129	.125	.122	.119	.116	.114	.112	.110	.109	.107	.106	12
400	.216	.188	.174	.164	.157	.150	.145	.140	.137	.133	.131	.128	.126	.124	.122	.120	.119	16
500	.237	.206	.190	.179	.172	.164	.158	.153	.149	.146	.143	.140	.138	.135	.133	.132	.130	20
600	.255	.222	.204	.193	.184	.176	.170	.165	.161	.157	.154	.151	.148	.146	.144	.142	.140	24
700	.271	.236	.217	.205	.196	.188	.181	.175	.171	.167	.163	.160	.158	.155	.153	.151	.149	28
800	.286	.247	.229	.216	.207	.197	.191	.185	.180	.176	.172	.169	.166	.164	.161	.159	.157	32
900	.299	.261	.240	.227	.217	.207	.200	.194	.189	.184	.181	.177	.174	.171	.169	.167	.164	36
1,000	.312	.272	.251	.237	.226	.216	.209	.202	.197	.192	.188	.185	.182	.179	.176	.174	.171	40
2,000	.412	.359	.331	.312	.299	.286	.275	.267	.260	.254	.249	.244	.240	.236	.232	.229	.226	80
3,000	.485	.422	.389	.367	.351	.336	.324	.314	.306	.299	.292	.287	.282	.277	.273	.270	.266	120
4,000	.544	.473	.437	.412	.392	.377	.363	.352	.343	.335	.328	.322	.316	.311	.307	.302	.299	160
5,000	.594	.522	.477	.450	.431	.412	.397	.385	.375	.366	.359	.352	.346	.340	.335	.331	.326	200
6,000	.639	.557	.513	.485	.463	.443	.427	.414	.403	.394	.386	.378	.372	.366	.361	.356	.351	240
7,000	.680	.592	.546	.515	.493	.471	.454	.441	.429	.419	.410	.403	.396	.389	.384	.378	.374	280
8,000	.717	.624	.576	.544	.520	.497	.479	.465	.453	.442	.433	.425	.417	.411	.405	.399	.394	320
9,000	.752	.655	.604	.570	.545	.521	.503	.487	.474	.463	.454	.445	.437	.431	.424	.418	.413	360
10,000	.784	.683	.630	.594	.568	.544	.524	.508	.495	.483	.473	.464	.456	.449	.442	.436	.431	400
20,000	1.035	.901	.831	.784	.750	.717	.692	.671	.653	.638	.624	.613	.602	.593	.584	.576	.568	800
30,000	1.217	1.060	.977	.922	.882	.844	.813	.789	.768	.750	.734	.721	.708	.697	.687	.677	.668	1,200
40,000	1.365	1.189	1.096	1.035	.990	.946	.913	.885	.862	.841	.824	.808	.794	.782	.770	.760	.750	1,600
50,000	1.493	1.312	1.198	1.131	1.082	1.035	.998	.967	.942	.920	.901	.884	.869	.855	.842	.831	.820	2,000
60,000	1.606	1.398	1.289	1.217	1.164	1.113	1.073	1.041	1.013	.990	.969	.951	.934	.919	.906	.894	.882	2,400
70,000	1.708	1.487	1.371	1.294	1.238	1.184	1.142	1.107	1.078	1.053	1.031	1.011	.994	.978	.964	.950	.938	2,800
80,000	1.802	1.569	1.446	1.366	1.306	1.249	1.204	1.168	1.137	1.110	1.087	1.067	1.048	1.032	1.017	1.003	.990	3,200
90,000	1.889	1.644	1.516	1.431	1.366	1.309	1.262	1.224	1.192	1.164	1.140	1.118	1.099	1.081	1.066	1.051	1.037	3,600
100,000	1.970	1.715	1.581	1.493	1.428	1.366	1.317	1.277	1.243	1.214	1.189	1.166	1.146	1.128	1.111	1.096	1.082	4,000

Formula: $d = \left(\frac{n^2}{h} \times \log.^{-1} 0.7732933 - 10\right)^{\frac{1}{5}} = \frac{1}{70}\left(\frac{n^2}{h}\right)^{\frac{1}{5}}$

d = Diameter in feet. n = Number of front feet. h = Fall per 100 feet.

St. Louis, April 8, 1880.

Robert Moore, Sewer Commissioner.

EXPERIMENT WITH A GAS ENGINE.

BY CHARLES A. SMITH,* MEMBER OF THE SOCIETY.

[Read June 2, 1881.]

It is thought that the following account of an experiment with a gas engine may be found interesting :

The engine in question is one of the "Otto Silent," and was made in Germany, at Cologne, and is used to operate a passenger elevator in the building occupied by the St. Louis Gas Light Company, at 511 Olive street, St. Louis.

The name given is on account of the noise made by the old "Otto and Langen" engines, and is hardly merited except by contrast; the principal noise, however, being that of the bevel gearing driving valve motion shaft, although by no means troublesome.

The dimensions of the engine are as follows: Cylinder, 9 inches diameter, 16 inches stroke ; revolutions per minute, 144 to 160 ; clearance in terms of stroke, 10 inches.

The engine is rated by the makers at 12 horse-power in the cylinder, and it is stated that they run at 21 cubic feet of gas per 1 horse-power per hour.

The action of the engine is of the "shot-gun order," an explosion of gas on the first outstroke being followed by the expulsion of the products on the instroke; and the second outstroke drawing in a mixture of gas and air, which on the second instroke is compressed, and at the commencement of the outstroke is exploded again. The engine thus makes four strokes, two complete revolutions to one working stroke, if allowed by the governor, which prevents the admission of gas if this speed is higher than a certain point: an arrangement which, while conducive to mechanical simplicity, is very far from perfect. The compression of the mixed air and gas is required to allow an explosion of the diluted mixture, and the dilution with excess air is desirable to keep the temperatures from becoming excessive. The cylinder is cooled by a water jacket, circulating from a tank. The explosion is produced by a secondary chamber and a light burning outside the cylinder.

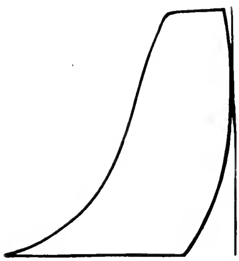
The experiments were made from February 12 to March 5, 1881, at intervals, and consisted of indicator diagrams from the cylinder, a record of the number of working strokes by a counter. The quantity of gas used was determined by a large meter belonging to the St. Louis Gas Light Co. The gas used for outside light was determined. The power given off by the pulley was determined by a friction brake held with a steel yard. The heating capacity of the gas was determined by experiment with a calorimeter, and found to be near that stated by Dr. Siemens, viz., 700 British heat units per cubic foot.

The results reached are as follows :

Average indicated horse-power (at 160 revolutions)... 11.6
" brake horse-power (at 160 revolutions)....... 9.4
" friction of machine horse-power (at 160 revolutions)............................ 2.2 = 19 per cent.
" efficiency of machine (at 160 revolutions)......... 81 " "

* The author is greatly indebted to Mr. John Sobolewski, Engineer of St. Louis Gas-Light Co., member of the Club, for valuable assistance, and for the use of meters and for help in calorimetric experiments.

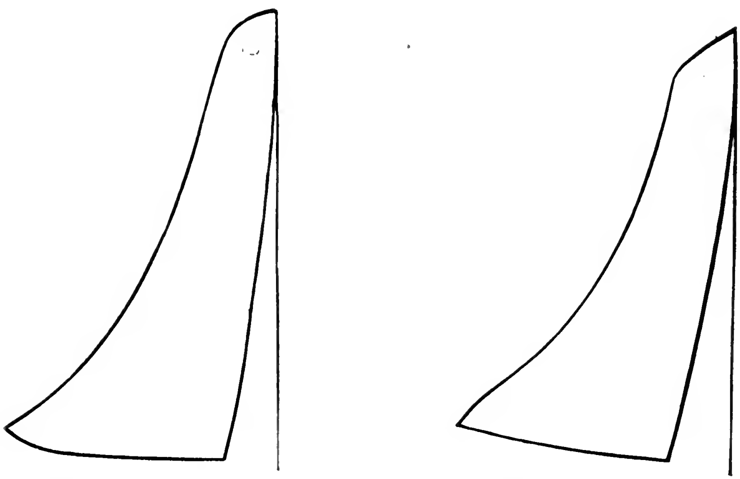
Average gas per stroke at pressure of about 2 in. water is 0.064 cu. ft., being a full quantity, when running 160 revolutions per min., of	307.2 cu. ft. per hour.
Gas used by lights per hour	3.5 " " "
Total	310.7 " " "
Cubic feet per hour gas per 1 horse-power	= 27
" " " " " effective horse-power	= 33.2
Water per hour for jacket	60 gallons.



The accompanying diagram represents very fairly all those taken. The actual average pressure is affected by the temperature of the cylinder rising therewith after continuous running.

Gas Engine : 9 ft. × 16 ft. × 100 lbs. spring.

We add for comparison some diagrams taken in England, copied from *Engineering.*



Gas Engine ; 6 in. × 12 in. × 160. See "Engineering," p. 198, Sept. 6, 1878.

Remarks upon the Results.—The increase of gas over that given by the circular is probably due to the fact that the terminal pressure is much greater than was obtained in the experiments in England by the Messrs. Crossley & Brother, of Manchester, from which the statement given by the circular is probably taken.

The friction of the engine is large, but it is continuous over four times the duration of the work. The shaft is so arranged that more spring occurs therein than is desirable.

The most notable feature, however, about the machine is its action as a

heat engine. Taking 27 cubic feet gas per 1 horse-power per hour, and 700 heat units per cubic foot, we have 18,900 heat units used per 1 horse-power per hour. Now a pound of first-class steam coal may be taken as having 15,000 heat units, thus bringing this engine to an equivalent of 1.26 pounds of coal per 1 horse-power per hour. The very best large steam engines made, those of Messrs. Leavitt, Corliss and John Elder & Co., have been brought to 1.5 pounds coal per 1 horse-power per hour.

As a question of cost of fuel, of course, gas at $2.25 per 1,000 cubic feet has little show: but with the coming use of fuel gas, the reduction in attendance and insurance make this little motor have a fair prospect, even in its present imperfect condition, of a dangerously close competition in cost of operation with the common class of steam engines, and the possibility seems open of a close struggle with the larger ones.

PROCEEDINGS.

CERTIFICATE OF INCORPORATION.

In the Circuit Court of St. Louis County, }
April Term, 1869. }

WEDNESDAY, April 12, 1869.

WHEREAS, Henry Flad, Geo. W. Fisher, Thos. J. Whitman, L. Fred'k Rice, T. A. Meysenburg, Wm. Eimbeck, Charles Pfeifer, C. E. Illsley, Geo. P. Herthel, Jr., Jos. P. Davis, and James Andrews, have filed, in the office of the Clerk of the Circuit Court, their Articles of Association, in compliance with the provisions of an "Act Concerning Corporations," approved March 19th, 1866, with their petition for incorporation under the name and style of the "Engineers' Club of St. Louis, Mo.;" they are, therefore, hereby declared a body politic and corporate, under the name and style aforesaid, with all the powers, privileges and immunities granted in the act above named.

By order of Circuit Court.

Attest:

JOHN LEWIS,

SEAL.

Clerk of the Circuit Court of St. Louis County.

CONSTITUTION.

ART. I.—This Association shall be known as "THE ENGINEERS' CLUB OF ST. LOUIS, MO."

ART. II.—Its objects shall be the educational improvement of its members and the encouragement of social intercourse among men of practical science. Among the means to be employed for attaining these objects shall be periodical meetings for the reading of professional papers and the discussion of scientific subjects, the foundation of a public library, the collection of maps, drawings and models, and the publication of such parts of the proceedings as may be deemed expedient.

Election of Members.

ART. III.—There shall be four classes of members: MEMBERS, CORRESPONDING MEMBERS, ASSOCIATE MEMBERS, and HONORARY MEMBERS.

ART. IV.—Members to be elected by ballot; one-fourth black balls to exclude. Members present not voting to be considered as voting in the affirmative.

ART. V.—Candidates for membership to be proposed by two members. Application for membership to be made to the Secretary. The Secretary to post all names of candidates, with the names of the members proposing the same, in

TABLE NO. I.

Table of Diameters in Feet of Circular Sewers Running Three-Fourths Full, with the Corresponding Velocities in Feet per Second.

Rainfall discharged, one inch per hour.

RATE OF INCLINATION IN FEET PER HUNDRED FEET.

Acres		.1	.15	.20	.25	.30	.35	.40	.45	.50	.55
1	Vel	1.60	1.89	2.12	2.32	2.49	2.61	2.78	2.93	3.05	3.18
	Dia	.99	.92	.87	.83	.80	.77	.75	.74	.72	.71
2	Vel	1.84	2.17	2.43	2.65	2.85	3.01	3.20	3.36	3.50	3.61
	Dia	1.31	1.21	1.14	1.09	1.05	1.02	.99	.97	.95	.93
3	Vel	1.99	2.35	2.63	2.88	3.10	3.30	3.48	3.64	3.81	3.95
	Dia	1.54	1.42	1.34	1.28	1.24	1.20	1.17	1.14	1.12	1.10
4	Vel	2.11	2.49	2.79	3.05	3.28	3.50	3.68	3.86	4.02	4.18
	Dia	1.73	1.60	1.51	1.44	1.39	1.35	1.31	1.28	1.25	1.23
5	Vel	2.22	2.61	2.92	3.20	3.44	3.65	3.85	4.04	4.23	4.38
	Dia	1.89	1.75	1.65	1.58	1.52	1.47	1.43	1.40	1.38	1.35
10	Vel	2.54	2.99	3.36	3.67	3.95	4.20	4.42	4.64	4.85	5.03
	Dia	2.50	2.31	2.18	2.08	2.01	1.95	1.89	1.85	1.82	1.78
15	Vel	2.76	3.24	3.64	3.98	4.28	4.55	4.81	5.04	5.24	5.41
	Dia	2.94	2.71	2.56	2.45	2.36	2.29	2.23	2.18	2.13	2.09
20	Vel	2.92	3.44	3.85	4.21	4.54	4.83	5.09	5.34	5.56	5.78
	Dia	3.30	3.04	2.87	2.74	2.65	2.57	2.50	2.45	2.39	2.35
25	Vel	3.05	3.59	4.03	4.41	4.74	5.05	5.32	5.58	5.81	6.04
	Dia	3.60	3.32	3.14	3.00	2.89	2.81	2.73	2.67	2.61	2.56
30	Vel	3.17	3.72	4.18	4.57	4.91	5.23	5.52	5.78	6.03	6.27
	Dia	3.88	3.57	3.38	3.23	3.11	3.02	2.94	2.87	2.81	2.76
35	Vel	3.27	3.84	4.31	4.71	5.07	5.39	5.68	5.96	6.22	6.46
	Dia	4.12	3.80	3.59	3.43	3.31	3.21	3.12	3.05	2.99	2.93
40	Vel	3.36	3.95	4.43	4.84	5.20	5.54	5.85	6.12	6.39	6.63
	Dia	4.35	4.01	3.79	3.62	3.49	3.39	3.30	3.22	3.15	3.09
45	Vel	3.44	4.04	4.53	4.95	5.33	5.67	5.98	6.27	6.53	6.79
	Dia	4.50	4.20	3.97	3.79	3.66	3.55	3.46	3.38	3.30	3.24
50	Vel	3.51	4.12	4.63	5.06	5.44	5.79	6.11	6.40	6.67	6.93
	Dia	4.75	4.38	4.11	3.96	3.81	3.70	3.60	3.52	3.44	3.38
60	Vel	3.64	4.28	4.80	5.25	5.65	6.00	6.34	6.64	6.93	7.20
	Dia	5.11	4.71	4.45	4.26	4.11	3.98	3.88	3.79	3.71	3.64
70	Vel	3.75	4.42	4.95	5.41	5.83	6.19	6.54	6.85	7.14	7.42
	Dia	5.44	5.02	4.74	4.53	4.37	4.23	4.12	4.03	3.94	3.87
80	Vel	3.85	4.53	5.08	5.56	5.98	6.36	6.71	7.04	7.34	7.62
	Dia	5.74	5.29	4.99	4.78	4.61	4.47	4.35	4.25	4.16	4.08
90	Vel	3.94	4.64	5.20	5.70	6.12	6.51	6.87	7.20	7.51	7.81
	Dia	6.01	5.54	5.23	5.01	4.83	4.68	4.56	4.45	4.36	4.28
100	Vel	4.03	4.74	5.32	5.81	6.25	6.65	7.01	7.35	7.67	7.97
	Dia	6.27	5.78	5.46	5.22	5.03	4.88	4.75	4.64	4.55	4.46
125	Vel	4.21	4.94	5.56	6.08	6.54	6.95	7.33	7.68	8.02	8.33
	Dia	6.86	6.32	5.97	5.71	5.51	5.33	5.19	5.07	4.97	4.88
150	Vel	4.37	5.14	5.76	6.30	6.78	7.21	7.61	7.97	8.32	8.61
	Dia	7.38	6.80	6.42	6.14	5.92	5.74	5.59	5.46	5.35	5.25
175	Vel	4.51	5.30	5.95	6.50	6.99	7.44	7.85	8.23	8.58	8.91
	Dia	7.85	7.23	6.83	6.53	6.30	6.11	5.95	5.81	5.69	5.58
200	Vel	4.63	5.44	6.11	6.68	7.18	7.64	8.06	8.45	8.81	9.15
	Dia	8.28	7.63	7.21	6.89	6.64	6.44	6.27	6.13	6.00	5.88
225	Vel	4.74	5.57	6.25	6.84	7.35	7.82	8.25	8.65	9.02	9.37
	Dia	8.67	8.00	7.55	7.22	6.96	6.75	6.57	6.42	6.29	6.17
250	Vel	4.84	5.69	6.39	6.98	7.51	7.99	8.43	8.83	9.21	9.57
	Dia	9.05	8.34	7.88	7.53	7.26	7.04	6.86	6.70	6.56	6.43
275	Vel	4.93	5.80	6.51	7.12	7.66	8.14	8.59	9.01	9.39	9.75
	Dia	9.40	8.67	8.18	7.83	7.55	7.32	7.12	6.96	6.81	6.68
300	Vel	5.02	5.90	6.61	7.24	7.78	8.29	8.74	9.16	9.55	9.93
	Dia	9.73	8.97	8.43	8.10	7.81	7.58	7.38	7.20	7.05	6.92
325	Vel	5.10	6.00	6.73	7.36	7.92	8.42	8.88	9.31	9.71	10.09
	Dia	10.05	9.27	8.75	8.37	8.07	7.82	7.62	7.44	7.28	7.15
350	Vel	5.17	6.10	6.83	7.47	8.03	8.55	9.01	9.45	9.85	10.24
	Dia	10.35	9.55	9.01	8.62	8.31	8.06	7.84	7.66	7.50	7.36
375	Vel	5.25	6.17	6.92	7.57	8.14	8.66	9.14	9.58	9.99	10.38
	Dia	10.64	9.81	9.26	8.86	8.53	8.28	8.06	7.88	7.71	7.57
400	Vel	5.32	6.25	7.02	7.67	8.25	8.78	9.26	9.70	10.12	10.51
	Dia	10.92	10.07	9.51	9.09	8.77	8.50	8.28	8.08	7.91	7.76
425	Vel	5.38	6.33	7.10	7.76	8.35	8.88	9.37	9.82	10.25	10.65
	Dia	11.19	10.31	9.74	9.31	8.98	8.71	8.48	8.28	8.11	7.96
450	Vel	5.44	6.40	7.18	7.85	8.45	8.98	9.47	9.93	10.36	10.77
	Dia	11.44	10.55	9.96	9.53	9.19	8.91	8.67	8.47	8.30	8.14
475	Vel	5.50	6.47	7.26	7.94	8.51	9.08	9.58	10.01	10.48	10.88
	Dia	11.69	10.78	10.18	9.74	9.39	9.10	8.86	8.66	8.48	8.32
500	Vel	5.56	6.51	7.33	8.02	8.63	9.17	9.68	10.15	10.58	10.99
	Dia	11.94	11.01	10.39	9.94	9.58	9.29	9.05	8.84	8.65	8.49
550	Vel	5.67	6.67	7.48	8.18	8.79	9.35	9.87	10.34	10.79	11.21
	Dia	12.40	11.44	10.80	10.33	9.96	9.65	9.40	9.18	8.99	8.82
600	Vel	5.76	6.78	7.61	8.32	8.95	9.52	10.04	10.53	10.98	11.40
	Dia	12.84	11.84	11.19	10.69	10.31	10.00	9.73	9.51	9.31	9.13
650	Vel	5.86	6.89	7.73	8.45	9.09	9.67	10.20	10.69	11.15	11.58
	Dia	13.26	12.23	11.54	11.04	10.64	10.32	10.05	9.82	9.61	9.43
700	Vel	5.94	6.99	7.85	8.58	9.22	9.81	10.35	10.86	11.32	11.76
	Dia	13.65	12.59	11.89	11.37	10.96	10.63	10.35	10.11	9.90	9.71
750	Vel	6.02	7.09	7.95	8.70	9.36	9.95	10.50	11.00	11.48	11.92
	Dia	14.03	12.94	12.22	11.69	11.27	10.93	10.64	10.39	10.18	9.98
800	Vel	6.11	7.18	8.05	8.81	9.47	10.08	10.63	11.14	11.62	12.07
	Dia	14.40	13.27	12.54	11.99	11.56	11.21	10.92	10.66	10.44	10.24
850	Vel	6.18	7.27	8.16	8.92	9.59	10.20	10.76	11.28	11.77	12.23
	Dia	14.76	13.61	12.85	12.29	11.85	11.49	11.19	10.93	10.70	10.50
900	Vel	6.25	7.35	8.25	9.02	9.70	10.32	10.88	11.41	11.90	12.37
	Dia	15.10	13.92	13.15	12.57	12.12	11.75	11.44	11.18	10.94	10.71
950	Vel	6.32	7.43	8.34	9.12	9.81	10.43	11.00	11.53	12.03	12.50
	Dia	15.43	14.23	13.43	12.85	12.39	12.01	11.69	11.42	11.18	10.97
1000	Vel	6.39	7.51	8.43	9.21	9.91	10.54	11.12	11.65	12.16	12.64
	Dia	15.75	14.52	13.71	13.11	12.64	12.26	11.91	11.66	11.42	11.20
Rate of Inclination		1	.15	.20	.25	.30	.35	.40	.45	.50	55

Acres		.60	.65	.70	.75	.80	.85	.90	.95	1.00	1.10	1.20
1	Vel	3.27	3.38	3.48	3.58	3.70	3.78	3.86	3.93	4.01	4.20	4.35
	Dia	.69	.68	.67	.66	.66	.65	.64	.63	.63	.62	.61
2	Vel	3.78	3.89	4.01	4.13	4.24	4.32	4.45	4.54	4.63	4.80	4.98
	Dia	.92	.90	.89	.88	.87	.85	.85	.84	.83	.81	.80
3	Vel	4.09	4.22	4.35	4.49	4.59	4.71	4.80	4.91	5.03	5.21	5.40
	Dia	1.08	1.06	1.05	1.04	1.02	1.01	.99	.98	.98	.96	.94
4	Vel	4.33	4.47	4.62	4.71	4.86	4.98	5.11	5.20	5.31	5.52	5.71
	Dia	1.21	1.19	1.18	1.16	1.14	1.13	1.12	1.10	1.09	1.07	1.05
5	Vel	4.53	4.68	4.82	4.98	5.09	5.20	5.33	5.45	5.57	5.77	5.97
	Dia	1.32	1.30	1.29	1.28	1.25	1.23	1.22	1.21	1.20	1.17	1.15
10	Vel	5.21	5.38	5.55	5.70	5.85	5.99	6.12	6.25	6.39	6.61	6.87
	Dia	1.75	1.72	1.70	1.67	1.65	1.63	1.61	1.59	1.58	1.55	1.52
15	Vel	5.64	5.82	6.00	6.18	6.31	6.50	6.63	6.78	6.93	7.21	7.48
	Dia	2.05	2.02	1.99	1.97	1.94	1.92	1.89	1.87	1.86	1.83	1.80
20	Vel	5.99	6.18	6.37	6.55	6.71	6.87	7.04	7.20	7.31	7.62	7.90
	Dia	2.31	2.27	2.24	2.21	2.18	2.15	2.13	2.11	2.08	2.04	2.01
25	Vel	6.26	6.46	6.65	6.84	7.02	7.19	7.35	7.52	7.68	7.97	8.25
	Dia	2.52	2.48	2.44	2.41	2.38	2.35	2.32	2.30	2.28	2.23	2.19
30	Vel	6.49	6.70	6.90	7.09	7.28	7.46	7.63	7.80	7.96	8.26	8.56
	Dia	2.71	2.67	2.63	2.59	2.56	2.53	2.50	2.47	2.45	2.40	2.36
35	Vel	6.69	6.91	7.12	7.32	7.50	7.69	7.87	8.04	8.20	8.52	8.83
	Dia	2.88	2.84	2.80	2.76	2.72	2.69	2.66	2.63	2.60	2.55	2.51
40	Vel	6.87	7.09	7.31	7.51	7.71	7.89	8.07	8.25	8.42	8.75	9.07
	Dia	3.04	2.99	2.95	2.91	2.87	2.83	2.80	2.77	2.74	2.69	2.65
45	Vel	7.03	7.26	7.48	7.69	7.89	8.08	8.27	8.46	8.62	8.96	9.28
	Dia	3.18	3.13	3.09	3.05	3.01	2.97	2.94	2.91	2.87	2.82	2.77
50	Vel	7.18	7.41	7.64	7.85	8.06	8.26	8.44	8.63	8.81	9.15	9.47
	Dia	3.32	3.27	3.22	3.18	3.14	3.10	3.06	3.03	3.00	2.94	2.89
60	Vel	7.45	7.69	7.93	8.15	8.36	8.57	8.77	8.95	9.14	9.50	9.83
	Dia	3.57	3.52	3.47	3.42	3.38	3.34	3.30	3.26	3.23	3.17	3.11
70	Vel	7.68	7.92	8.17	8.40	8.62	8.84	9.04	9.24	9.42	9.79	10.14
	Dia	3.80	3.74	3.68	3.63	3.59	3.55	3.51	3.47	3.43	3.37	3.31
80	Vel	7.89	8.15	8.40	8.62	8.86	9.07	9.28	9.48	9.68	10.05	10.41
	Dia	4.01	3.95	3.89	3.83	3.79	3.74	3.70	3.66	3.62	3.55	3.49
90	Vel	8.08	8.34	8.60	8.83	9.07	9.29	9.49	9.70	9.91	10.29	10.65
	Dia	4.20	4.14	4.08	4.02	3.97	3.92	3.87	3.83	3.79	3.72	3.66
100	Vel	8.25	8.52	8.78	9.02	9.26	9.48	9.70	9.92	10.13	10.51	10.88
	Dia	4.38	4.31	4.25	4.19	4.14	4.09	4.04	4.00	3.96	3.88	3.81
125	Vel	8.62	8.91	9.18	9.43	9.68	9.92	10.15	10.36	10.57	11.00	11.38
	Dia	4.79	4.72	4.67	4.58	4.52	4.47	4.42	4.37	4.32	4.25	4.17
150	Vel	8.95	9.23	9.52	9.78	10.01	10.29	10.52	10.75	10.97	11.41	11.81
	Dia	5.16	5.07	5.00	4.93	4.87	4.81	4.75	4.70	4.65	4.57	4.49
175	Vel	9.24	9.52	9.82	10.09	10.36	10.61	10.86	11.09	11.32	11.76	12.17
	Dia	5.48	5.39	5.32	5.24	5.18	5.12	5.06	5.00	4.95	4.86	4.77
200	Vel	9.47	9.78	10.08	10.36	10.63	10.89	11.14	11.38	11.62	12.07	12.50
	Dia	5.78	5.69	5.61	5.53	5.46	5.39	5.33	5.27	5.22	5.12	5.03
225	Vel	9.70	10.02	10.32	10.61	10.88	11.15	11.41	11.66	11.90	12.37	12.81
	Dia	6.06	5.97	5.88	5.80	5.72	5.65	5.59	5.53	5.47	5.37	5.28
250	Vel	9.91	10.23	10.54	10.84	11.12	11.39	11.65	11.91	12.16	12.63	13.08
	Dia	6.32	6.22	6.13	6.05	5.97	5.90	5.83	5.77	5.71	5.60	5.51
275	Vel	10.10	10.43	10.74	11.04	11.33	11.62	11.88	12.14	12.39	12.87	13.33
	Dia	6.57	6.46	6.37	6.28	6.20	6.13	6.06	5.99	5.93	5.82	5.72
300	Vel	10.28	10.61	10.94	11.24	11.53	11.84	12.09	12.35	12.61	13.10	13.56
	Dia	6.80	6.69	6.60	6.51	6.42	6.34	6.27	6.20	6.14	6.03	5.92
325	Vel	10.44	10.78	11.11	11.42	11.72	12.01	12.29	12.56	12.81	13.31	13.78
	Dia	7.02	6.91	6.81	6.72	6.63	6.55	6.48	6.41	6.34	6.22	6.11
350	Vel	10.60	10.95	11.28	11.59	11.89	12.18	12.47	12.74	13.00	13.51	13.99
	Dia	7.23	7.12	7.02	6.92	6.83	6.75	6.67	6.60	6.53	6.41	6.30
375	Vel	10.75	11.10	11.43	11.75	12.06	12.36	12.64	12.91	13.18	13.70	14.18
	Dia	7.44	7.32	7.21	7.11	7.02	6.94	6.86	6.78	6.71	6.59	6.47
400	Vel	10.89	11.24	11.58	11.90	12.22	12.52	12.81	13.08	13.35	13.87	14.36
	Dia	7.63	7.51	7.40	7.30	7.21	7.12	7.04	6.96	6.89	6.76	6.64
425	Vel	11.02	11.38	11.72	12.05	12.36	12.66	12.96	13.24	13.52	14.05	14.54
	Dia	7.82	7.69	7.58	7.48	7.38	7.29	7.21	7.13	7.06	6.93	6.80
450	Vel	11.15	11.51	11.86	12.19	12.50	12.81	13.11	13.40	13.67	14.21	14.70
	Dia	8.00	7.87	7.76	7.65	7.55	7.46	7.38	7.30	7.22	7.09	6.96
475	Vel	11.26	11.64	11.94	12.32	12.64	12.95	13.25	13.54	13.82	14.36	14.86
	Dia	8.17	8.04	7.93	7.82	7.72	7.62	7.54	7.46	7.38	7.24	7.11
500	Vel	11.38	11.75	12.11	12.45	12.77	13.08	13.39	13.68	13.96	14.51	15.02
	Dia	8.34	8.21	8.09	7.98	7.88	7.78	7.69	7.61	7.53	7.39	7.26
550	Vel	11.60	11.98	12.51	12.69	13.01	13.33	13.64	13.94	14.23	14.79	15.31
	Dia	8.67	8.53	8.41	8.29	8.18	8.08	7.99	7.90	7.82	7.68	7.55
600	Vel	11.80	12.19	12.56	12.91	13.24	13.57	13.89	14.19	14.48	15.05	15.58
	Dia	8.97	8.84	8.70	8.58	8.47	8.37	8.28	8.19	8.10	7.95	7.81
650	Vel	12.00	12.39	12.76	13.12	13.46	13.79	14.11	14.42	14.71	15.29	15.82
	Dia	9.27	9.12	8.99	8.86	8.75	8.64	8.54	8.45	8.36	8.21	8.06
700	Vel	12.18	12.57	12.95	13.31	13.66	13.99	14.32	14.64	14.91	15.52	16.07
	Dia	9.55	9.39	9.26	9.13	9.01	8.90	8.80	8.71	8.62	8.46	8.31
750	Vel	12.31	12.74	13.13	13.49	13.85	14.19	14.52	14.84	15.11	15.73	16.29
	Dia	9.81	9.65	9.51	9.38	9.26	9.15	9.05	8.95	8.86	8.69	8.54
800	Vel	12.51	12.91	13.30	13.67	14.03	14.37	14.70	15.02	15.34	15.94	16.50
	Dia	10.07	9.91	9.76	9.63	9.51	9.39	9.28	9.18	9.09	8.92	8.77
850	Vel	12.65	13.07	13.45	13.83	14.20	14.55	14.88	15.21	15.72	16.13	16.70
	Dia	10.31	10.15	10.00	9.86	9.74	9.62	9.51	9.40	9.31	9.14	8.98
900	Vel	12.81	13.22	13.62	14.00	14.36	14.71	15.06	15.39	15.71	16.32	16.90
	Dia	10.55	10.39	10.23	10.09	9.96	9.84	9.73	9.63	9.53	9.35	9.19
950	Vel	12.94	13.36	13.76	14.15	14.52	14.88	15.22	15.56	15.87	16.49	17.08
	Dia	10.78	10.61	10.45	10.31	10.18	10.06	9.94	9.84	9.74	9.55	9.39
1000	Vel	13.08	13.50	13.91	14.30	14.67	15.03	15.38	15.71	16.01	16.66	17.25
	Dia	11.01	10.83	10.67	10.53	10.39	10.27	10.15	10.04	9.91	9.75	9.58
Rate of Inclination		60	.65	.70	.75	.80	.85	.90	.95	1.00	1.10	1.20

Acres		1.25	1.30	1.40	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00		Acres
1	Vel	4.40	4.45	4.62	4.71	5.03	5.33	5.56	5.80	6.02	6.23	6.42	6.66	6.83	7.05	Vel	1
	Dia	.60	.59	.59	.58	.56	.55	.54	.52	.51	.50	.49	.49	.48	.48	Dia	
2	Vel	5.05	5.15	5.32	5.43	5.80	6.10	6.38	6.68	6.95	7.16	7.39	7.61	7.88	8.07	Vel	2
	Dia	.79	.79	.78	.76	.74	.72	.70	.69	.68	.66	.65	.64	.64	.63	Dia	
3	Vel	5.48	5.55	5.74	5.91	6.27	6.63	6.95	7.24	7.49	7.78	8.04	8.30	8.52	8.75	Vel	3
	Dia	.93	.92	.91	.90	.87	.85	.83	.81	.79	.78	.77	.76	.75	.74	Dia	
4	Vel	5.80	5.88	6.08	6.26	6.66	7.01	7.36	7.67	7.95	8.27	8.51	8.77	9.03	9.27	Vel	4
	Dia	1.04	1.03	1.02	1.01	.98	.95	.93	.91	.89	.88	.86	.85	.84	.83	Dia	
5	Vel	6.07	6.17	6.37	6.56	7.00	7.34	7.70	8.04	8.35	8.63	8.94	9.18	9.45	9.71	Vel	5
	Dia	1.14	1.13	1.12	1.11	1.08	1.04	1.02	1.00	.98	.96	.95	.93	.92	.91	Dia	
10	Vel	7.00	7.10	7.30	7.53	8.02	8.45	8.83	9.21	9.62	9.97	10.29	10.60	10.88	11.15	Vel	10
	Dia	1.51	1.50	1.47	1.46	1.42	1.38	1.34	1.32	1.30	1.28	1.26	1.24	1.22	1.20	Dia	
15	Vel	7.57	7.69	7.92	8.15	8.67	9.16	9.59	10.01	10.40	10.76	11.12	11.46	11.78	12.08	Vel	15
	Dia	1.77	1.76	1.74	1.71	1.66	1.62	1.58	1.55	1.52	1.49	1.47	1.45	1.43	1.41	Dia	
20	Vel	8.01	8.16	8.40	8.64	9.18	9.71	10.18	10.61	11.00	11.39	11.75	12.11	12.46	12.79	Vel	20
	Dia	2.00	1.98	1.95	1.92	1.86	1.82	1.78	1.74	1.70	1.67	1.64	1.62	1.60	1.58	Dia	
25	Vel	8.38	8.53	8.78	9.03	9.59	10.12	10.63	11.09	11.50	11.92	12.30	12.66	13.03	13.48	Vel	25
	Dia	2.17	2.16	2.13	2.10	2.03	1.98	1.94	1.90	1.86	1.83	1.80	1.77	1.75	1.73	Dia	
30	Vel	8.70	8.84	9.11	9.37	9.96	10.50	11.00	11.49	11.93	12.37	12.78	13.15	13.51	13.87	Vel	30
	Dia	2.34	2.32	2.29	2.26	2.19	2.13	2.08	2.04	2.00	1.97	1.94	1.91	1.88	1.86	Dia	
35	Vel	8.98	9.12	9.38	9.65	10.27	10.84	11.35	11.85	12.31	12.74	13.16	13.56	13.93	14.28	Vel	35
	Dia	2.49	2.47	2.43	2.40	2.33	2.27	2.21	2.17	2.13	2.09	2.06	2.03	2.00	1.97	Dia	
40	Vel	9.22	9.37	9.65	9.91	10.56	11.12	11.65	12.17	12.66	13.10	13.51	13.92	14.31	14.67	Vel	40
	Dia	2.63	2.61	2.57	2.53	2.46	2.39	2.33	2.29	2.25	2.21	2.17	2.14	2.11	2.08	Dia	
45	Vel	9.43	9.59	9.87	10.14	10.79	11.40	11.95	12.47	12.93	13.39	13.82	14.25	14.64	15.02	Vel	45
	Dia	2.75	2.73	2.69	2.65	2.57	2.51	2.45	2.40	2.35	2.31	2.27	2.24	2.21	2.18	Dia	
50	Vel	9.64	9.79	10.09	10.37	11.01	11.62	12.18	12.72	13.21	13.68	14.12	14.56	14.97	15.36	Vel	50
	Dia	2.87	2.85	2.81	2.77	2.68	2.61	2.55	2.50	2.45	2.41	2.37	2.34	2.31	2.28	Dia	
60	Vel	10.00	10.15	10.46	10.75	11.42	12.06	12.65	13.19	13.68	14.18	14.64	15.08	15.52	15.93	Vel	60
	Dia	3.09	3.06	3.02	2.98	2.88	2.81	2.75	2.69	2.63	2.59	2.55	2.51	2.48	2.45	Dia	
70	Vel	10.30	10.41	10.79	11.09	11.79	12.44	13.04	13.60	14.10	14.61	15.10	15.55	16.00	16.41	Vel	70
	Dia	3.28	3.24	3.21	3.17	3.07	2.99	2.92	2.86	2.80	2.75	2.71	2.67	2.63	2.60	Dia	
80	Vel	10.58	10.78	11.08	11.39	12.11	12.77	13.39	14.02	14.52	15.03	15.51	15.98	16.42	16.85	Vel	80
	Dia	3.46	3.42	3.39	3.34	3.24	3.15	3.08	3.02	2.96	2.91	2.86	2.82	2.78	2.74	Dia	
90	Vel	10.84	11.01	11.35	11.66	12.39	13.07	13.72	14.39	14.85	15.38	15.88	16.34	16.80	17.24	Vel	90
	Dia	3.63	3.60	3.55	3.50	3.39	3.30	3.23	3.16	3.10	3.05	3.00	2.95	2.91	2.87	Dia	
100	Vel	11.06	11.23	11.58	11.90	12.64	13.35	14.00	14.59	15.16	15.71	16.22	16.70	17.18	17.62	Vel	100
	Dia	3.78	3.75	3.70	3.65	3.53	3.44	3.37	3.29	3.23	3.18	3.13	3.08	3.04	3.00	Dia	
125	Vel	11.58	11.76	12.11	12.45	13.24	13.97	14.64	15.26	15.85	16.42	16.96	17.47	17.95	18.43	Vel	125
	Dia	4.14	4.11	4.05	3.99	3.87	3.77	3.68	3.60	3.53	3.47	3.42	3.37	3.32	3.28	Dia	
150	Vel	12.00	12.18	12.56	12.90	13.73	14.48	15.18	15.84	16.44	17.01	17.59	18.11	18.62	19.11	Vel	150
	Dia	4.45	4.41	4.35	4.29	4.16	4.05	3.96	3.88	3.80	3.71	3.68	3.62	3.57	3.53	Dia	
175	Vel	12.37	12.56	12.95	13.32	14.17	14.94	15.66	16.33	16.96	17.56	18.14	18.68	19.21	19.71	Vel	175
	Dia	4.73	4.69	4.63	4.57	4.43	4.31	4.21	4.12	4.04	3.97	3.91	3.85	3.80	3.75	Dia	
200	Vel	12.71	12.91	13.30	13.67	14.55	15.34	16.08	16.77	17.44	18.04	18.61	19.20	19.74	20.25	Vel	200
	Dia	4.99	4.95	4.88	4.81	4.67	4.55	4.44	4.35	4.27	4.19	4.13	4.07	4.01	3.96	Dia	
225	Vel	13.01	13.22	13.62	14.00	14.90	15.71	16.46	17.18	17.81	18.46	19.07	19.65	20.19	20.73	Vel	225
	Dia	5.23	5.19	5.12	5.05	4.90	4.77	4.65	4.56	4.47	4.39	4.32	4.26	4.20	4.15	Dia	
250	Vel	13.29	13.51	13.90	14.30	15.21	16.04	16.81	17.53	18.22	18.86	19.48	20.08	20.64	21.18	Vel	250
	Dia	5.46	5.42	5.33	5.26	5.11	4.97	4.85	4.75	4.66	4.58	4.51	4.45	4.39	4.33	Dia	
275	Vel	13.54	13.76	14.17	14.57	15.49	16.34	17.13	17.88	18.58	19.23	19.86	20.46	21.02	21.58	Vel	275
	Dia	5.67	5.63	5.54	5.47	5.30	5.16	5.04	4.94	4.85	4.76	4.69	4.62	4.55	4.50	Dia	
300	Vel	13.78	14.01	14.42	14.83	15.77	16.64	17.44	18.18	18.87	19.56	20.20	20.81	21.38	21.96	Vel	300
	Dia	5.87	5.81	5.74	5.66	5.49	5.35	5.22	5.11	5.02	4.93	4.85	4.78	4.71	4.66	Dia	
325	Vel	14.01	14.23	14.66	15.07	16.03	16.91	17.72	18.49	19.20	19.88	20.53	21.16	21.74	22.32	Vel	325
	Dia	6.07	6.02	5.93	5.85	5.67	5.52	5.39	5.28	5.18	5.09	5.01	4.94	4.87	4.81	Dia	
350	Vel	14.22	14.44	14.88	15.29	16.26	17.16	17.97	18.76	19.48	20.17	20.83	21.45	22.05	22.61	Vel	350
	Dia	6.25	6.20	6.11	6.02	5.84	5.69	5.55	5.44	5.33	5.24	5.16	5.08	5.01	4.95	Dia	
375	Vel	14.42	14.64	15.09	15.50	16.49	17.40	18.22	19.02	19.77	20.46	21.14	21.77	22.38	22.96	Vel	375
	Dia	6.42	6.37	6.28	6.19	6.00	5.85	5.71	5.59	5.49	5.39	5.31	5.23	5.16	5.10	Dia	
400	Vel	14.60	14.84	15.28	15.70	16.70	17.62	18.47	19.27	20.03	[illegible]	21.38	22.03	22.66	23.25	Vel	400
	Dia	6.59	6.54	6.44	6.35	6.16	6.00	5.86	5.74	5.63	5.53	5.44	5.36	5.29	5.22	Dia	
425	Vel	14.78	15.02	15.47	15.90	16.91	17.84	18.69	19.51	20.27	20.98	21.67	22.32	22.94	23.54	Vel	425
	Dia	6.75	6.70	6.60	6.51	6.31	6.15	6.00	5.88	5.77	5.67	5.58	5.50	5.42	5.35	Dia	
450	Vel	14.95	15.18	15.64	16.08	17.10	18.04	18.90	19.72	20.49	21.22	21.91	22.56	23.19	23.80	Vel	450
	Dia	6.91	6.85	6.75	6.66	6.46	6.29	6.14	6.01	5.90	5.80	5.70	5.62	5.54	5.47	Dia	
475	Vel	15.11	15.35	15.81	16.26	17.29	18.25	19.13	19.93	20.72	21.46	22.15	22.82	23.46	24.06	Vel	475
	Dia	7.06	7.00	6.90	6.81	6.60	6.43	6.28	6.14	6.03	5.93	5.83	5.75	5.67	5.59	Dia	
500	Vel	15.27	15.51	15.97	16.43	17.48	18.43	19.32	20.14	20.92	21.67	22.37	23.04	23.69	24.31	Vel	500
	Dia	7.21	7.15	7.04	6.95	6.74	6.56	6.41	6.27	6.15	6.05	5.95	5.86	5.78	5.71	Dia	
550	Vel	15.57	15.80	16.29	16.74	17.81	18.78	19.70	20.54	21.33	22.08	22.80	23.49	24.15	24.79	Vel	550
	Dia	7.49	7.43	7.32	7.22	7.00	6.81	6.67	6.52	6.39	6.28	6.18	6.09	6.01	5.93	Dia	
600	Vel	15.84	16.08	16.57	17.02	18.12	19.10	20.03	20.90	21.71	22.48	23.21	23.91	24.57	25.22	Vel	600
	Dia	7.75	7.69	7.58	7.47	7.25	7.05	6.89	6.75	6.62	6.51	6.40	6.31	6.22	6.14	Dia	
650	Vel	16.09	16.35	16.85	17.31	18.41	19.41	20.35	21.24	22.05	22.81	23.58	24.29	24.96	25.62	Vel	650
	Dia	8.00	7.94	7.83	7.72	7.48	7.28	7.11	6.97	6.83	6.72	6.61	6.51	6.42	6.34	Dia	
700	Vel	16.33	16.59	17.09	17.57	18.69	19.70	20.66	21.57	22.40	23.18	23.93	24.66	25.33	26.00	Vel	700
	Dia	8.24	8.18	8.06	7.95	7.71	7.50	7.33	7.18	7.05	6.92	6.81	6.71	6.61	6.53	Dia	
750	Vel	16.56	16.82	17.32	17.81	18.96	19.98	20.94	21.85	22.70	23.50	24.27	25.00	25.69	26.38	Vel	750
	Dia	8.47	8.41	8.28	8.17	7.92	7.71	7.53	7.38	7.24	7.11	7.00	6.90	6.80	6.72	Dia	
800	Vel	16.77	17.04	17.55	18.04	19.19	20.24	21.21	22.15	23.00	23.81	24.58	25.33	26.03	26.71	Vel	800
	Dia	8.69	8.63	8.50	8.38	8.13	7.91	7.73	7.58	7.43	7.30	7.18	7.08	6.98	6.89	Dia	
850	Vel	16.97	17.25	17.77	18.26	19.45	20.49	21.48	22.41	23.28	24.10	24.88	25.63	26.35	27.04	Vel	850
	Dia	8.90	8.81	8.71	8.59	8.33	8.11	7.92	7.76	7.61	7.48	7.36	7.25	7.15	7.06	Dia	
900	Vel	17.17	17.44	17.97	18.47	19.64	20.73	21.72	22.65	23.53	24.37	25.17	25.93	26.66	27.31	Vel	900
	Dia	9.11	9.01	8.91	8.79	8.52	8.30	8.10	7.93	7.78	7.65	7.53	7.42	7.32	7.22	Dia	
950	Vel	17.36	17.63	18.16	18.67	19.86	20.97	21.96	22.91	23.79	24.63	25.43	26.19	26.93	27.62	Vel	950
	Dia	9.31	9.21	9.10	8.98	8.71	8.48	8.28	8.11	7.95	7.81	7.69	7.57	7.47	7.37	Dia	
1000	Vel	17.53	17.81	18.35	18.86	20.07	21.16	22.18	23.11	24.01	24.80	25.70	26.48	27.23	27.93	Vel	1000
	Dia	9.50	9.43	9.29	9.16	8.80	8.67	8.45	8.28	8.12	7.98	7.85	7.71	7.61	7.53	Dia	
Rate of Inclination		1.25	1.30	1.10	1.50	1.75	2.00	2.25	2.50	2.75	3.00	3.25	3.50	3.75	4.00		Rate of Inclination

some conspicuous place in the rooms of the Association, for at least two weeks previous to a vote being taken thereon.

Art. VI.—Members and Associate Members shall be persons who are or have been engaged in the practice of engineering or pursuits connected therewith. Associates shall have all the rights and privileges of members, except the rights of voting and holding office.

Art. VII.—Corresponding Members to be persons of the same description who reside at distances too great for attendance at the regular meetings.

Art. VIII.—Honorary Members shall be persons eminent in engineering; the number not to exceed ten. They may be elected, on the recommendation of five members, by an unanimous vote.

Art. IX.—In case of the non-election of any person balloted for, no notice shall be taken thereof in the minutes.

Art. X.—Persons elected shall be notified by the Secretary, and shall not be considered members unless their acceptance is received within two months.

Art. XI.—All persons duly elected shall be members of the Club, on paying the initiation fee and signing the Constitution.

Art. XII.—Members desiring a transfer from one class to another shall apply to the Secretary, stating their reasons for such change.

The Secretary to report, and a vote to be taken, under the same regulations as for the election of candidates.

Election and Duties of Officers and Committee.

Art. XIII.—The officers of the Association to consist of a President, Vice-President, Treasurer and Secretary, who are to be elected at a general meeting of the members, by ballot.

Art. XIV.—A committee of three, on Finance, Library and Publication to be appointed by the President.

Art. XV.—Two members of the Committee will constitute a quorum for the transaction of business.

Art. XVI.—The Committee to control the finances of the Club; to examine all papers to be read before or presented to the Association; to report upon the advisability of having such papers read published or copied; and to recommend the purchase of books and periodicals.

Art. XVII.—The President to be a member of the Committee, who shall call a special meeting on the requisition of any two of its members.

Art. XVIII.—The President, and in his absence the Vice-President, to preside at the meetings.

Art. XIX.—The Treasurer shall have charge of the funds of the Club, receive all assessments, and pay all bills approved by the Finance Committee. The Treasurer shall be an *ex-officio* member of the Committee on Finance and Publication.

Art. XX.—The Secretary to keep books and papers of the Association and to record the minutes of the transactions at the meetings.

Art. XXI.—The Secretary shall be an *ex-officio* member of the Committee.

Art. XXII.—The books and papers of the Association to be open for the inspection of any member.

Subscriptions, etc.

Art. XXIII.—Members and Corresponding Members to pay an initiation fee of twelve (12) dollars, and an annual subscription of not exceeding ten (10) dollars. Associates to pay an initiation fee of five (5) dollars, and an annual subscription of not exceeding five (5) dollars.

The dues of Members are to be $2.50, and of Associates $1.25, payable quarterly, in advance.

ART. XXIV.—Persons whose subscriptions are in arrear for the previous year are not qualified to vote.

ART. XXV.—Persons whose subscriptions are in arrear for two years may be struck off the list of the Association by a majority of the members voting.

Meetings, etc.

ART. XXVI.—Officers shall be elected at the regular meeting, on the evening of the first Wednesday in December of each year.

ART. XXVII.—The Club shall meet on Wednesday evenings.

ART. XXVIII.—Special meetings shall be called by the President.

ART. XXIX.—The President, Vice-President, or in their absence the President pro tem., to have the power of directing the manner of discussion, and his decision shall be final.

ART. XXX.—Seven members shall constitute a quorum for the transaction of business, but the acti n of a less number at a weekly meeting, provided a quorum be not present, may be entered on the journal if such action does not affect the rights of the Association.

ART. XXXI.—The Constitution may be altered or amended by a two-thirds vote of the members present at any regular meeting at which not less than ten (10) members are present, provided such amendment has been prepared in writing, and seconded at a previous regular meeting; provided, however, that if ten (10) such members do not attend at the regular meeting, it may be amended by a unanimous vote, there being the usual business quorum of seven (7) present.

BY-LAWS.

I. The following order to be observed in the transaction of business at all regular meetings, unless set aside by a vote of the members present:

1. The reading of the records of the previous meeting.
2. Report of Committees.
3. Candidates for admission balloted for.
4. Communications received by the Committee (Finance, Library and Publication) since the last meeting to be read, if recommended.
5. Unfinished business.
6. Discussions.

II. If required by one-fifth of the whole number of members present, the ayes and noes upon any question shall be called and entered upon the journal.

III. Special committees for the investigation of scientific subjects, connected with the objects of the Association, to be appointed by the President.

IV. Visitors introduced by members to enter their names, with member's name introducing, in a book to be provided for that purpose.

V. A record of all donations to be kept by the Secretary, with the names of the donors.

VI. A book shall be kept by the Secretary, in which members may enter the title of any book, map, or plan which they wish to have added to the library.

VII. Additions and amendments may be made to the By-Laws at any regular meeting, provided they have been proposed in writing and seconded at a previous regular meeting.

VIII. All debates to be conducted according to the rules laid down in "Cushing's Manual."

IX. Whenever any person is elected to membership of this Club, the Secretary shall immediately inform him of his election by a letter of the following form:

"SIR: You are hereby informed that on the —— day of ——, 18—, you were duly elected a —— member of the Engineers' Club of St. Louis, Mo., but in conformity to the regulations of this Club you cannot become an active mem-

ber until you have signed the Constitution and By-Laws, and otherwise complied with the rules and regulations regarding new members.

"I am yours truly,

"—— ——, *Secretary.*"

X. Whenever any member fails to pay his initiation fee or assessments within two weeks after the same falls due, the Treasurer shall send him a letter of the following form :

"SIR : The regulations of this Club require me to inform you that your dues (initiation fee or assessments), amounting to —— dollars, have been in arrear for two weeks. It is requested that you will order the payment thereof.

"I am yours truly,

"—— ——, *Treasurer.*"

XI. Upon discussion of the merits of any invention or other subject of interest to this Club, no vote shall be taken, and all record of debate upon such subject shall be deemed secret.

WESTERN SOCIETY OF ENGINEERS.

ORGANIZED 1869.

TRANSACTIONS.

THE WATER SUPPLY OF THE TORONTO, GREY & BRUCE RAILWAY, ILLUSTRATIVE OF THE SYSTEM EMPLOYED AND KNOWN AS THE HAGGAS ELEVATOR SYSTEM.

By Edmund Wragge, General Manager Toronto, Grey & Bruce Railway, (M. I. C. E. London).

[Read September 13, 1881.]

The Haggas Elevator System, having been in use to the exclusion of other methods of water supply upon the Toronto, Grey & Bruce Railway, since November, 1878, it is thought that a short descriptive account of the works, their cost and character, as well as a description of the system, may be useful to others who are desirous of effecting a similar saving to that which has been made on the railway in question.

The attention of the author of this paper was called to the invention, and having carefully looked into the matter, he decided in the summer of 1878, to recommend the Directors of the Toronto, Grey & Bruce Railway Company to equip the whole of their line with the necessary apparatus, and if found satisfactory to abandon the whole system of tank-houses. This was accordingly done, and having received permission to make the change, it was carried out as follows :

The Toronto, Grey & Bruce Railway has a total length of 191 miles, the main line extending from Toronto to Owen Sound, a distance of 122 miles, with a branch from Orangeville (53 miles from Toronto) to Teeswater, 69 miles in length. In its route to Owen Sound it passes over a summit, the level of which is 1,460 feet above that of Lake Ontario at Toronto, and throughout its course it keeps mainly on the water-shed of all the streams; passing the sources of the principal rivers which flow into Lake Ontario, Lake Erie, Lake Huron and the Georgian Bay. This elevation is probably the highest of any railway in Ontario, and consequently the climate is exceedingly cold and severe.

The railway was constructed in 1870 to 1873, and was fitted up with ordinary tank-houses, in some of which steam pumps and in other hand pumps were used, with the exception of two points (where frost-proof tanks had been erected since the original construction), these tank-houses have

been kept from freezing by means of stoves. Trouble was always experienced more or less from the old tanks and pipes freezing, and there was always a necessity in winter for keeping the fires going by night as well as by day. The traffic on the railway being light rendered the expense of keeping on men at night to look after the fires very onerous and on the branch to Teeswater, there being only two trains a day each way, the expenses were very heavy in proportion to the service required.

The tanks on the line were as follows:

River Humber frost-proof tank, with steam pump, 16 miles from Toronto.

Kleinburg tank-house, hand pump, 21 miles from Toronto.

Nixon's tank-house, hand pump, 35 miles from Toronto.

Charleston tank-house, worked in summer by hydraulic ram, 42 miles from Toronto.

Orangeville tank-house, filled by gravitation, 49 miles from Toronto.

Shelburne tank-house, hand pump, 60 miles from Toronto.

Dundalk tank-house, hand pump, 73 miles from Toronto.

Flesherton tank-house, hand pump, 85 miles from Toronto.

Markdale tank-house, steam pump, 93 miles from Toronto.

Chatsworth tank-house, steam pump, 109 miles from Toronto.

Owen Sound tank at engine-house, with steam pump, 122 miles from Toronto.

ON THE BRANCH.

Waldemar tank-house, hand pump, 59 miles from Toronto.

Arthur tank-house, hand pump, 76 miles from Toronto.

Mount Forest, frost proof tank, with steam pump, 86 miles from Toronto.

Harriston tank-house, steam pump, 95 miles from Toronto.

Wroxeter tank-house, hand pump, 108 miles from Toronto.

Teeswater tank, in engine-house, with steam pump, 122 miles from Toronto.

The total cost of the whole of this system amounted to $14,666, or $77 per mile of railway, and the annual expenditure for the water supply and repairs to tank-houses was in the year ending June 30:

1874	$4,671.00	1877	$5,496.00
1875	5,830.00	1878	4,587.00
1876	5,336.00		

added to which the city water-works in Toronto received the sum of $500 a year for water for engines and for washing out purposes.

The new system consists in building an underground tank into which a pipe is placed and the water drawn therefrom by means of a Haggas water elevator (which is a form of steam injector), by coupling the elevator (which is attached to the locomotive) to the stand-pipe in the tank by means of a short piece of wired india-rubber hose, and drawing the water therefrom by suction and forcing it into the tender. Tanks were put down for this purpose at various points along the line, wherever it was found that a supply could be advantageously obtained, without reference to their being necessarily at a station; and in practice it is found that while passenger trains can generally succeed in getting all the water they require at those tanks which were placed at the stations, intermediate ones work very conveniently for the engines of freight trains.

At Toronto a pipe was laid into Lake Ontario, which supplies a wooden tank 8 feet in diameter and 8 feet deep, the surface of the water averaging about 6 feet from the rail level. Two tanks, each 10 feet in diameter and 8 feet deep, one on each side of the track, were put down at Humber Summit Station, 15 miles from Toronto, and the

water there is obtained from springs, which have to be conducted by drains to the tanks, as the supply is rather limited. The surface of the water is only some 2 feet 6 inches from rail level: and as the supply from the springs in dry weather is not very great, the tanks were made sufficiently large to accumulate all the water which would run in between the passage of trains, without allowing any of it to run to waste. At Kleinburg the well which was sunk for the previous tank-house was made use of by being connected with the new tank, which was put down alongside the track.

It is necessary at all these places to have two tanks—one on each side of the track—for the elevator being fixed on the driver's side of the engine there must be tank and pipe for connection with the elevator whichever way the engine may be running.

At Nixons, tanks 8 feet in diameter and 8 feet deep were put down, and there is a living stream of water at this place, the surface of which is only some 6 feet below rail level. At Charleston a small dam was constructed some 3 feet in height by 30 feet in length, which pens up the water so that it flows into the tanks, which are 8 feet in diameter and 8 feet deep, and makes the surface of the water 6 feet below rail level; the bottom at this place consisting of rocks and large bowlders, this was considered the most economical way of fixing the tanks, which are banked around (as at all other places where they are not sunk into the original ground) with earthwork 3 feet in width at the top of the tank, and allowed to run off to a natural slope. At Orangeville the original tank-house with water obtained by gravitation has been allowed to remain, as it is attached to the engine-house at that place, and used also for washing out purposes. At Shelburne there is a living stream and the tanks are the same as at Nixons, but this tank is situated 3 miles south of Shelburne station. The Dundalk tanks are also situated 3 miles south of Dundalk station, and are sunk in a swamp through which the road runs for upwards of 2 miles, the ditches on either side, which were dug to form the embankment of the railway, acting as storage reservoirs to keep up the supply.

Proceeding northward there are tanks at Markdale Station, where there is a living stream of water. The same remark applies to Chatsworth. At Owen Sound there is only one tank, placed at the intersection of two tracks, adjoining the river Sydenham, the water from which flows into it through a pipe. At all these points north of Orangeville water is obtained at a level not exceeding 6 feet below rail level.

On the Teeswater Branch the first tanks are 3 miles west of Waldemar, and the level of the water in them averages 8 feet below rail level. A small dam, some 2 feet in height, has been built across the stream, from which the supply is taken to raise the level of the water to the above-mentioned height. The next tanks are at mile 82, 20 miles from the last-mentioned one, and the water at that point is obtained from springs running from a gravel hill in the immediate neighborhood. The water at this point is obtained at a level of about 4 feet below rail level. Harriston Station, 95 miles from Toronto, is the place where the next tanks are, and the water there is about 6 feet below rail level. Two more tanks are placed at Gorrie, 107

miles from Toronto, and two more at a point 5 miles east of Teeswater, while, as a reserve, the old system is retained at the Teeswater engine-shed.

The total cost of fitting up the whole of the railway with this work, the tanks being made of 3-inch pine, spiked in three curbs made of 4 by 2-inch pine and covered over with an elevated box for pipe, as shown on the accompanying plans, was $1,805.39, exclusive of royalty for the use of the patent.

There are twenty locomotive engines in use upon the railway, each of which has been fitted up with one of the elevators at a cost of $50 per engine. The elevator is bolted underneath the cab of the engine, and the steam-pipe, 1¼-inch in diameter, taken from the top of the boiler inside the cab to feed it. The portable suction pipe, which has an inside diameter of 4 inches, with a turned cast-iron socket at each end, is 3 feet in length, and is strongly wired with steel wire to prevent its collapsing when under pressure. The 4-inch pipe is permanently fixed on the tender, the elbow at the upper part standing up so that the lower face of the bend is about 6 inches above the level of the water in the tender, to prevent slopping over when full from the motion of the water. The connection between the engine and tender is made by means of 4-inch hose, with an ordinary hose connection.

It has been the endeavor in equipping this railway to make the lift of water in all cases as light as possible, as the rapidity of the discharge depends upon having a light lift. With a lift not exceeding 8 feet from the surface of the water to rail level, the elevator will supply 450 gallons of water per minute into the tender, with a pressure of steam of 135 pounds per square inch; and the steam being mixed with water as it passes into the tender heats it from 25 to 30 degrees. It is found that by keeping up a good fire, by means of the blower, the necessary supply of water can always be taken, say from 1,200 to 1,500 gallons, without altering the pressure of the steam in the boiler, and the steam so used is not wasted, as the temperature of the water is increased to an equal value.

The total cost of repairs and maintenance of both locomotives and tanks and their appurtenances for the two and a half years ending on the 31st of March last has been $592.84, representing an annual expenditure of $237.14.

Some of the inconveniences of the old system of water-tanks have already been mentioned. They may be briefly enumerated as follows:

1. Heavy original cost.
2. Trouble to prevent freezing.
3. Expense of pumping water.
4. Expense of fuel for warming tank-houses.

The disadvantages which have been found in connection with the new system may be stated as follows:

1. That water cannot always be obtained at a suitable level at the most convenient points for taking water. But of this more hereafter.

2. The length of time occupied in taking water—this being only at the rate of 450 gallons per minute—is probably twice the time occupied in filling from overhead tanks; but is a small matter on most railways, rep-

resenting only a loss of from 5 to 10 minutes per 100 miles, time which may be advantageously occupied in oiling engine.

3. Inconvenience has been found occasionally in summer from the water in the tank being too warm for the old class of injectors to put into the boiler, but no difficulty is experienced under this head by the use either of pumps or of the new class of injector, which should always be able to force the water from the tender to the boiler at a temperature of 120 degrees, a heat which is never obtained from the Haggas elevator.

4. Occasionally the ordinary stand-pipes in the tanks have in severe weather (owing to their being improperly protected or put down in a hurry) been found to freeze. The remedy for this is quick and effective. The portable hose is attached to the stand pipe in the usual way, but instead of being attached to the Haggas elevator it is placed to the waste pipe from the injector, and steam blown down it, and it will be readily seen that the steam will very quickly thaw the surface of ice in the pipe. It may be mentioned, however, in this connection that the necessity for this has not occurred upon this railway more than half a dozen times during the three winters it has been in use, and this would not occur if pipes were regularly and frequently used. On the occasion of engines being fast in the snow, and water unobtainable, a portable hose is attached to the elevator, and fed with snow either by shovels or by being rammed into the snow-bank. The tender is then supplied with water by the snow being sucked up and melted by the steam, instead of the snow being shoveled directly into the tank.

Although there are no points where water has not been readily obtainable at the requisite level, on the line of the Toronto, Grey & Bruce Railway, there need be no difficulty experienced from this source upon railways wherever wind-mills and frost-proof tanks can be used. The author would recommend, under such circumstances, that the wind-mills should pump water into underground tanks, which would of course be frost-proof, and require less cost in maintaining in repair than ordinary overhead frost-proof tanks: and besides cost very much less to construct in the first instance. Underground tanks may also be fed by gravitation, wherever available, more readily than overhead tanks. At the Orangeville station of the Toronto, Grey & Bruce Railway previously mentioned it is intended during the present season to place underground tanks at each end of the station yard, fed by means of pipes laid through the yard from the overhead tanks already mentioned as being in use at the station. There are many places where pipes can be connected in this way at each end of a station yard, or in several places in a large yard, allowing any number of engines to take water at the same time, as in many instances there is a sufficient fall through the yard to enable this to be done, which is an obvious advantage. In places where the water is muddy it may be allowed to run through a filter into the tanks, an advantage which is very desirable in some localities, and the necessity for which is obvious.

For washing-out purposes the same underground tanks may be made use of, and the washing done by means of the steam pump. This is in practice, I understand, on the Toronto and Nipissing Railway. The Prince Edward Island Railway, 200 miles in length, has been entirely

fitted with the Haggas Elevator system in the manner set forth in Appendix A; and 170 miles of the Canadian Pacific Railway have been fitted with this system, as set forth in Appendix B.

APPENDIX A.

The Prince Edward Island Railroad (a government road) is about 200 miles long, and was originally fitted up with the ordinary elevated tanks and wind-mills at a cost of from $15,000 to $20,000. The annual outlay for maintenance was $5,000. Last summer, by order of Sir Chas. Tupper, Minister of railways and canals, it was equipped with the "Haggas Water Elevator" system; fifteen water stations, which are underground and frost-proof, have been supplied at a cost, exclusive of royalty, of $2,750. Nine elevated tanks, nine wind-mills and four other pumps have been dispensed with, and the annual maintenance, on the completion of a few necessary alterations, will be reduced to a mere trifle—say $100.

APPENDIX B.

The first 170 miles of the Canadian Pacific Railway west from Thunder Bay was equipped last summer with the "Haggas" system, giving thirteen water stations complete at a total cost, exclusive of royalty, of $4,100. The outlay for maintenance will be very trifling. If on this section of the railway the old system of elevated tanks with wind-mills and the ordinary pumping apparatus had been adopted, the first cost would have been upward of $30,000, and $5,000 would have been required annually for maintenance. Special attention is respectfully directed to the economical results here indicated.

PROCEEDINGS.

NOVEMBER 1, 1881:—The 134th regular meeting was held at 4 P. M., Vice-President Cregier in the chair.

The minutes of the preceding meeting were read and approved.

Application to be admitted as a member was presented from Mr. Irving A. Stearns, mining and civil engineer, of Wilkesbarre, Pa.; indorsed by Messrs. Tutton, Baker and Forsyth.

Upon ballot, Mr. Clare Lovelace, civil engineer, No. 320 Fulton street, Chicago, indorsed by Messrs. Randolph, Powell and C. J. Bates; also, Mr. John Alexander Low Waddell, of Council Bluffs, Ia., indorsed by Messrs. C. J. Bates, W. S. Bates and W. S. McHarg, were elected members.

The Secretary announced that two gentlemen who had been elected members had failed to pay their initiation fees within the limit of time prescribed by the Constitution. A resolution was passed directing the Secretary to send duplicate notices of their election to these members. The Secretary was also directed to ascertain if the paper read at the 131st meeting had been published in any professional or scientific periodical, and, if not so published, to have it printed with the papers of the Society.

[*Adjourned.*]

Mr. Charles Jenny, civil engineer, from Vienna, Austria, was present at the meeting, and was introduced to the members present.

L. P. MOREHOUSE, Secretary.

NOVEMBER 15, 1881:—The 135th regular meeting was held at 7:30 p. m. Mr. Randolph was called to the chair.

The minutes of the preceding meeting were read and approved.

No quorum being present, after a general discussion of several matters of professional interest, the meeting adjourned. L. P. MOREHOUSE, Secretary.

DECEMBER 6, 1881:—The 136th regular meeting was held at 4 P. M., Vice-President Cregier in tne chair.

The minutes of the preceding meeting were read and approved.

Upon ballot, Mr. Irving A. Stearns, mining and civil engineer, Wilkesbarre, Pa., whose application, presented at the 134th meeting, was indorsed by Messrs. Tutton, Baker and Forsyth, was elected a member.

It was voted that a payment be made to the *American Engineer* of $150, on account of publication of the Society's proceedings, in part, during the current year.

It was also voted that, as soon as the catalogue of books in the library should be completed by the Librarian and printed, the papers and proceedings published for the Society by the *American Engineer* during this year should be bound with the catalogue, and a copy of the volume be sent to each member.

Mr. Benezette Williams offered the followiug preamble and resolutions, which were adopted:

Whereas, The Board of Managers of the Association of Engineering Societies will be able to secure a number of exchanges for the JOURNAL OF THE ASSOCIATION, and

Whereas, It is the conclusion of the Board of Managers that the best way for disposing of these exchanges will be to let each of the Association Societies, as far as possible, fill its subscription list of periodicals from the exchange list of the Association, therefore,

Resolved, That the Secretary and Librarian be authorized to fill the subscription list of the Western Society of Engineers from the exchange list of the Association of Engineering Societies, as far as practicable, payment to be made to the Association at the publisher's price to the Society where subscription is made direct.

Mr. Williams presented a series of fifteen stereoscopic views, donated to the Society by Mr. E. Prince, of Quincy, Ill., illustrating breaks in the Sny Island Cove during the high water, July, 1880.

The Secretary was directed to return the thanks of the Society to Mr. Prince.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

ORGANIZED 1880.

TRANSACTIONS.

ARCHING WOODEN HOWE TRUSSES AND SOME OBSERVATIONS ON WOODEN BRIDGES.

By Gustav Lindenthal, Member of the Society.

[Read August 7, 1880.]

There are on many railroads in the United States badly proportioned Howe truss bridges, built years ago, at a time when the sizes and dimensions of a bridge were generally left to the judgment and thumb rules of the bridge carpenter. As a rule, the rods are very weak; sometimes, also, the braces, chords and floor-beams. Such of them as have yet sound and fair timber, could be used for a number of years yet before being replaced by iron bridges, provided they could be strengthened sufficiently to carry the increased load of modern freight-engines and trains. Frequently this is done by the addition of wooden arches, abutting either against the ends of the bottom chord or against the masonry of the abutments. It is everywhere admitted that the "arching" does relieve the trusses, and that it strengthens the wooden bridge; but it is also the common saying that it is useless to lay down any rule for proportioning an arched truss, because it cannot be ascertained how one system affects the other, and to what extent the old truss and the new arch can be made to work together.

It must be conceded that this cannot be done with nicety; but the engineer at least should be able to ascertain approximately the value of the arch for any weak case, that he is called upon to help. Sometimes the bottom chord is strong enough to take up the side thrust of the arch, while the abutments may be too weak for it. Sometimes it is safer to abut the arch against the masonry, and indeed this latter way is preferable in every instance where the masonry is strong enough to withstand the thrust without cracking or settling.

To illustrate and examine the way in which the arch relieves the truss let us select for an example a 100-foot span (over all), Howe through-bridge (with dimensions of members as used about 10 years ago), 92.5 feet centre

to centre of end angle blocks = 10 panels 9.25 feet each; height 22 feet centre to centre of chords; width, 15 feet in clear.

$$\text{Top chord} \left\{ \begin{array}{l} \text{Two } 6 \times 12 \\ \text{Two } 7 \times 12 \end{array} \right\} = 312 \,\square'' \text{ gross section throughout.}$$

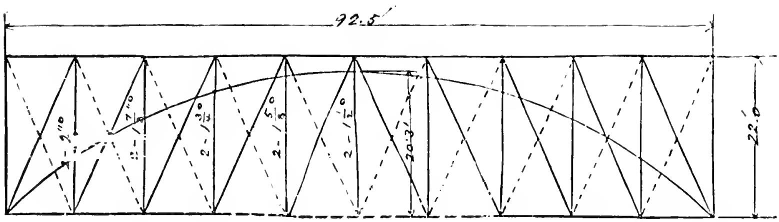


Fig. 1.

$$\text{Bottom chord} \left\{ \begin{array}{l} \text{Two } 6 \times 14 \\ \text{Two } 7 \times 14 \end{array} \right\} = 280 \,\square'' \text{ net section } (364 \,\square'' \text{ gross section throughout}).$$

Let this be an instance, where the arch is to abut against the ends of the bottom chord.

Dead load of bridge assumed at 1,100 pounds per lineal foot of bridge.

Live load: two consolidation engines followed by a train weighing one (gross) ton per lineal foot.

The resulting maximum strain in two middle panels of bottom chord would be 103,200 pounds (without an arch).

It is a safe practice to drop one leaf, to allow for splicing, keys, bolts, etc., to get the effective area of bottom chord for tension and bending moment combined. This area is here

$$\left\{ \begin{array}{l} \text{Two } 7 \times 14 \\ \text{One } 6 \times 14 \end{array} \right\} = 280 \,\square''$$

The bending moment on the bottom chord from floor-beams for a maximum panel load of 28,000 pounds (L. L. + D. L.) and the chord considered as a continuous beam will equal very near

$$\frac{\text{Width} \times 14^2}{6} \times 800 = \frac{5}{8} \; \frac{28{,}000 \times 9.25 \times 12}{8}$$

resulting width = 9.3 inches for 14 inches height = 130 square inches required for bending moment. For tension are required $\frac{103{,}200}{800} = 129$ square inches necessary total = 130 + 129 = 259 square inches against 280 square inches actually in the chord. This shows that the bottom chord would be strong enough; but all the rods are too weak (and some sets of braces), and they are to be relieved by arches abutting against the ends of bottom chord.

There are two conditions to be fulfilled :

1. The bottom chord must be yet entirely safe after taking up the side thrust of the arch.

2. The braces and rods must be relieved of sufficient load to make them safe also.

To ascertain the first condition let us assume the extreme case, namely, the truss to be an arch truss only (of the same D. L. as the Howe truss); height of arch at centre of span = 20.3 feet centre to centre of chords.

For an arched truss the maximum tension throughout the bottom

chord equals the compression in crown of arch, in this case 111,800 pounds.

Required area $\frac{111,800}{800}$ = 140 sq. in. for tension.

130 sq. in. for bend. mom., which remains the same.

Necessary 270 sq. in.

280 sq. in. actual in the chord.

This shows that were the arch to carry the whole live and dead load (omitting here the weight of the arch) the bottom chord would be strong enough to resist the combined tension and bending moment, produced by such load. The increase of 4.2 per cent. over area of bottom chord in Howe truss is of course in consequence of the lesser height of arch. The difference would be that the chord strains in the arch truss would be the same through the whole length of bottom chord, while in a Howe truss they are diminishing toward the ends.

The first condition is shown to be fulfilled.

For the second condition let us first find the maxima strains in rods in truss without an arch.

They are in short :

1. 84,600 on 4.48 □ ″ net section of rods at base of thread, 18,900 lbs. strain per □ ″.
2. 69,500 on 3.84 □ ″ net section of rods at base of thread, 18,100 lbs. strain per □ ″.
3. 55,500 on 3.38 □ ″ net section of rods at base of thread, 16,700 lbs. strain per □ ″.
4. 42,400 on 2.84 □ ″ net section of rods at base of thread, 14,900 lbs. strain per □ ″.
5. 32,000 on 2.46 □ ″ net section of rods at base of thread, 13,000 lbs. strain per □ ″.

The highest strain per square inch is in the first set of rods = 18.900 pounds per square inch ; it should not be more than 12,500, considering that the bridge is to remain only a limited number of years ; it ought not be more than 10.000 pounds per square inch for an entirely safe and permanent structure.

The strain in the first set of rods should not be more than 4.48 square inches × 12,500 pounds = 56.000 pounds. The remaining (84.600—56.000) 28.600 pounds shall be taken up by the arch.

The arch can practically be likened to a parabola, which will for an equally distributed load from first to last panel take up an equal component at each panel point.

The maximum stress in first set of rods occurs for a load extending from it to the furthermost abutment. It is a cumulative strain. Hence we can assume that $28.600 = \frac{1}{10}\ (9 + 8 + 7 + 6 + 5 + 4 + 3 + 2 + 1) \times$ vertical component. From this equation, vertical component = 6.360 pounds.

The condition of strains changes evidently for a moving load ; since, advancing on the bridge and arriving, for instance, at *a* it would tend to deform the arch ; it would deflect at *a* and rise somewhere at *b*.

It could not do so without lifting a proportionate weight of the truss at *b*. Insomuch then it will also participate in carrying a certain portion of the unequal load, and resist, to a certain extent, the deranging effect of the same ; with what relief to the rods need only to be considered after the

load reaches the middle of the bridge, because only then the rods begin to acquire their maximum strain.

The maximum strain in middle set of rods occurs for a load extending

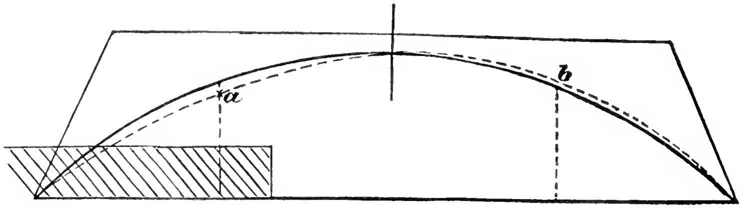


Fig. 2.

from the middle to one abutment: it is here 32,000 pounds (without the arch).

The arch is to be firmly connected at its middle with the Howe truss, and we can assume it to be hinged there. Then it will resist (approximately and without regard to its bending moment as a stiff arch) deforming to the extent of one panel load of dead weight (5,100 pounds) at each loading point.

The result would be $= 32{,}000 - \frac{1}{10}\ (4 + 3 + 2 + 1)\ 5{,}100 = 26{,}900$ as strain in the middle rods (when trusses are arched); 26,900 pounds for 2.46 square inches = 10,900 pounds per square inch.

This is an entirely safe result, because a consideration of the arch as a stiff arch would give a more favorable result; but it could not be arrived at without going into complicated theorems, very little to the purpose in a wooden Howe bridge.

For the load moving beyond the middle of the bridge the proportion of load taken up by the arch becomes obviously greater, till it reaches its maximum for a load extending over the whole bridge.

Hence the arch does relieve the rods and braces as anticipated.

To proportion the arch let us for simplicity assume for it the same radius of gyration as for the top chord, so we can say that truss and arch sustain the maximum load in proportion to equal resulting maximum strain per square inch in top chord and arch.

We have ascertained before that the maximum panel load for the arch should be 6,360 pounds; or $9 \times 6{,}360 = 57{,}200$ pounds; for the whole arch the maximum live load plus dead load is 196,400 pounds for the whole span; $196{,}400 - 57{,}200 = 139{,}200$ pounds is the portion on the truss. Maximum strain in top chord results as follows:

$$312 \,\square'' \times \text{strain per } \square'' = \frac{139{,}200 \times 92.5}{8 \times 22} \quad \frac{139{,}200 \times 9.25}{2 \times 10 \times 22} = 70{,}300$$

$$\text{Strain per square inch of top chord} = \frac{70{,}300}{312} = 225 \text{ lbs.}$$

For the arch we have:

57,200 live load.
5,700 dead load of arch.
62,900 lbs. total.

Strain in crown of arch equal to tension in bottom chord=

$$\frac{62{,}900 \times 92.5}{8 \times 20.3} = 35{,}800 \text{ lbs.}$$

$$\text{Strain at foot of arch} = \sqrt{35,800^2 + \left(\frac{62,900}{2}\right)^2} = 47,100 \text{ lbs.}$$

$$\frac{47,100 \text{ lbs.}}{225 \text{ lbs. per sq. in.}} = 209 \text{ sq. in.}$$

required section of arch at foot.

$$\frac{35,800}{225 \text{ lbs. per sq. in.}} = 160 \text{ sq. in.}$$

required at crown of arch. Four pieces 7 × 8 inches (224 square inches) would, in this case, be sufficient, including allowance for keying, bolts, etc.

The strains in bottom chord, commencing from the end, would be as follows:

From load on truss.	From load on arch.	Total.
26,500	35,800	62,300
47,100	35,800	71,300
61,400	35,800	97,200
70,100	35,800	105,900
73,000	35,800	108,800

$$\frac{108,800}{800 \text{ lbs. per } \square''} = \begin{array}{l} 136 \ \square'' \text{ for tension.} \\ \underline{130 \ \square'' \text{ for bending moment.}} \\ \underline{266 \ \square'' \text{ necessary.}} \\ 280 \ \square'' \text{ actually in the chord.} \end{array}$$

This shows that in cases like the one presented here the arch may safely abut against the ends of the bottom chord, and that it would materially relieve the rods and braces.

Due regard must be given to an adjustment of the arch and to the detail of connecting the same with the truss; especially is this necessary when an old bridge is to be arched. The bottom chords have to be carefully examined in every detail, whether the splicing is efficient, whether it is of cast iron or wrought iron, or of oak wood, as in many old wooden bridges. The above-named practice of dropping one leaf in bottom chord to arrive at the effective section applies only for a carefully adjusted, thoroughly bolted bottom chord, with wrought-iron splices. For any other kind of splicing, the arches should not abut against the bottom chord. As mentioned above, wherever possible, the arch should abut against the stone abutments, and in this case a similar process for finding the value of the arch can be used. The bottom chord would then, too, be relieved of a portion of its strain, likewise with the other members of the truss.

Any calculation of a wooden bridge, or of a wooden arch, is apt to be knocked on the head by an incompetent and bad adjustment of the truss rods. It is nothing uncommon to find wooden railroad and highway bridges strained down by too tightly screwed up rods. That class of bridge carpenters who have a quite fabulous conception of the strength of iron, and no conception, of course, of the strains in a truss frame, is yet quite frequent. I have seen an instance where a small Howe truss was just being put up. A man adjusted the rods with a 3½-foot wrench; he was screwing up the nuts ("screwing up a strain") so hard that the screw end of a 1-inch rod was pulled off and the nut hissed through the air with the velocity of a bullet. The man did not seem much astonished, and to my questions remarked that it happens frequently, because the iron is

sometimes very bad and will not stand the strain. From some more remarks it appeared that he had no knowledge of iron. When I told him that the fracture shows a good iron and that he broke the rod by screwing it too tight, and that most likely the other rods adjusted in the same way may be strained so they have a permanent set and are not safe, then he remarked, quite surprised, that from long experience he knows exactly how to do his work, and that the fault is not his but with the bad iron.

Another cause of uncertain strain in truss rods of wooden bridges is their contraction at a low temperature, while the timber of the bridge is practically not affected by it. This strain can become very considerable sometimes. Assume, for instance, that the Howe truss bridge mentioned above had been adjusted at a middle temperature with such nicety that the rods take no other than their allotted strain from the D. + L. load, in this case for the first set of rods (2 rods 2 inches diameter not upset), 2.24 square inches, 84,600 pounds, or 18,900 pounds per square inch of area at base of threads.

For an extreme change in temperature of 120° or 60° down from the assumed middle temperature the rods will contract $\frac{1}{3000}$ of their length, or $\frac{3}{32}$ inch. The resulting strains from contractions alone for E = 26,000,000, would be

$$\frac{26{,}000{,}000 \times 0.094 \times 3.142 \ \square \text{ in.}}{282 \text{ in.}} = 12{,}200$$

pounds per square inch at weakest place—namely, at base of threads. The maximum strain in one rod would then be

$$\left.\begin{matrix} 18{,}900 \\ +\,12{,}200 \end{matrix}\right\} = 31{,}100 \text{ lbs. per } \square \text{ in.}$$

more than enough to cause a permanent set in the screw end of the rod. This may be yet called a favorable sample, because there are much weaker rods used in old Howe trusses.

The uncertain strains caused by bad adjustment and by temperature, make it advisable to take thicker rods than otherwise would be necessary for the strains from live and dead load alone. They should be adjusted at least twice a year, in spring and fall, and they should have upset screw ends by all means. The closest inspection fails often to detect weakened or partially fractured screw ends in rods that are not upset, because they are not visible. Furthermore, by using upset rods (so upset that on testing they will break in the body of the rod, instead of the screw end) a permanent set, and with it danger to the bridge, can be more readily detected. Good common iron stretches 12 to 15 per cent. before it fractures. This elongation takes place for the whole length of rods that are upset, but for rods not upset it will of course take place only between the nut and the beginning of the threads. In the first place it may elongate 20 to 30 inches, in the latter case only ½ inch to 1 inch before the rod breaks.

Notwithstanding the great saving in iron and cost, and the *greater safety* of upset rods, there are yet instances of bridges being built with rods not upset, particularly where the building of bridges is left to so-called "practical bridge builders," who do not believe in upset rods, as if it were a matter of belief. Consider that wooden bridges, as a rule, have been built with rods so weak (indeed, there are instances where the strain from dead load alone exceeded 12,000 pounds per square inch), then the wonder is, that we do not hear of more bridges breaking down. It is commonly

asserted that a wooden bridge is safer than an iron one, and that more iron bridges break down than wooden ones. Whether this is so or not is of no concern to any one who knows how to build a bridge properly. The fact is, that a wooden bridge is better watched than an iron one. There is the danger from fire, the timber is expected to rot and decay, therefore, it is oftener looked after, and if a trace of danger appears, it is more readily detected than in a badly proportioned iron bridge, which is left to take care of itself.

On the point of economy it may be remarked that a wooden bridge is not very much cheaper than an iron one, even at first cost, while it is the dearest kind of a bridge in the long run. A wooden bridge built as per specifications of the N. Y., P. & O. R. R. will cost only 8 to 12 per cent. less than an iron bridge of the same capacity. The above-named specifications provide for the same margin of safety in both kinds of bridges. A wooden bridge will have a greater dead load, and for spans over 120 feet the trusses become enormously heavy and ponderous for modern freight loads. The quality of timber is decreasing every year, and there is hardly a wooden bridge that will last ten years if not covered; and if covered it will cost as much, if not more, than an iron bridge; besides, the cost of maintenance is great, not to speak of the necessity of having a watchman at every more important bridge to watch it against the danger from fire. Take for comparison some figures from an estimate for an 140-foot span single track railroad bridge.

An iron span complete would cost	$6,300
A wooden span complete would cost	5,500
Saving in first cost	$800

Six per cent. interest on $800 saved on first cost will amount to $480 in 10 years, barely enough to cover the expense of maintenance, adjusting, etc. After 10 years the wooden bridge will be so rotten as to require rebuilding, while the iron bridge will need only one coat of paint and a renewal of the ties, $200. Some officials are so fond of wood that they will go on to rebuild rotten bridges with new wooden bridges twice and thrice over again.

After 10 years the iron bridge will cost	$6,500
" 20 " " " " " "	6,700
" 30 " " " " " "	6,900

The wooden bridge after 10 years will cost...	$5,500 + $6,300	=	$11,800
" " " " 20 " " " ...	+ 6,300	=	18,100
" " " " 30 " " " ...	+ 6,300	=	24,400

After 30 years this wooden bridge would cost 3.8 times as much as an iron bridge. There seems to be an inherited notion that wood is cheaper than iron, dating from a time when iron cost 10 to 12 cents a pound of manufactured bridge, and also from a time when a net ton per lineal foot of bridge was considered the extreme live load for short and long spans alike. Yet there are many occasions where a wooden bridge may be preferable; for instance, where a new road is being built into a sparsely settled country, when the engineer in charge is required to keep within certain low limits in cost, and where light engines and rolling stock are to be used, or, as in war, when rapidity of construction is required: in all such cases a wooden bridge has yet its advantageous uses. But on older roads with an established business, it is certainly bad policy to con-

tinue to build wooden bridges. Still this is done, and badly proportioned bridges are erected in the old fogy way, without plan or strain-sheet, without specification, and, of course, with rods not upset, relying simply on thumb-rules and the fact that a similar bridge, built years ago, has not come down yet. While in railroad practice such poor engineering is casually yet indulged in, in highway practice is it yet more frequently to be witnessed. Nearly every bridge engineer is aware of the astounding amount of pigheadedness and stupidity to be met with in so-called "highway work," so that first-class bridge builders have become disgusted with it long ago and refuse to have anything to do with the practices of fraud and official ignorance.

Consider that a well-proportioned iron bridge kept well painted will last 300 to 500 years; that it will last as long if not outlast the stone abutments, then you will perceive the importance of building a *good* bridge. But there are yet officials on railroads and in charge of public works who have an inadequate sense of their responsibility and duty, and persist in their unscientific and obsolete way of discharging it. Often a railroad can afford to pay $80,000 to $100,000 lawyer's fees a year, while it claims that it cannot afford to make its bridges safe, or rebuild an unsafe bridge at a cost of a few thousand dollars.

But progress is discernible also in that direction, and as all you, gentlemen, believe in the laws of evolution, let us hope for a time when good bridges will be built everywhere; when trains will not break through badly constructed structures; when a thick mass of people can safely stand on a bridge, looking at a boat race or a swimming suit exhibition, with the trusses bristling with small and big urchins sitting on them; when even circus elephants will not test the safety of a patented country bridge any more and wade through the water rather than risk their lives in passing over the bridge, when all such and similar happenings will be considered evoluted possibilities.

COMPARISON OF THE DEFLECTIONS OF THE HOWE TRUSS AND PARABOLIC BOWSTRING OF SAME SPAN AND SAME CENTRAL HEIGHT.*

By John D. Crehore, Member of the Club.

[Read October 2, 1880.]

I. Let the two girders be independent of each other, and take

$l = 2a = 200$ feet = span of each.

$h = 20$ feet = central height of parabolic girder and uniform height of the Howe, except for the two end panels, which vary from 20 feet to 0.

$n = 14$ = number of panels.

$l \div n = \dfrac{200}{14} = 14\frac{2}{7}$ feet = panel length.

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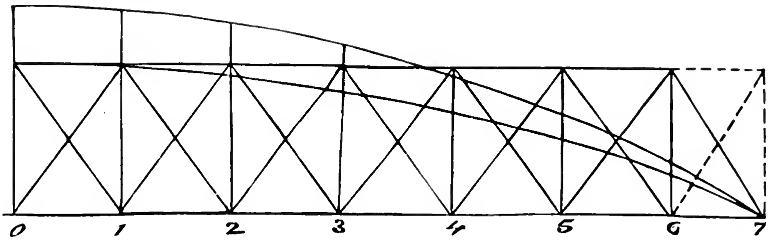
*[The following formulæ for deflection, used by Mr. Crehore at the October meeting in 1880, were not intended for publication with the club papers, being extracts from his orthcoming engineering work, but were solicited for insertion here as bearing upon the subject of Mr. Lindenthal's paper.—M. E. R.]

Then the height of the parabolic girder at any point, x, is

$$y = \left(1 - \frac{4x^2}{l^2}\right) h,$$

the origin being at the centre of bottom chord. Or, if r denote the num-



ber of any panel-point, counting from the centre to the right, we may put $\frac{rl}{n}$ for x, and find the height at each panel point thus:

$$y = \left(1 - \frac{4r^2}{n^2}\right) h$$

$y = 20.$ where $r = 0$	$y = 13.46944$ where $r = 4$
$y = 19.59184$ where $r = 1$	$y = 9.79600$ where $r = 5$
$y = 18.36736$ where $r = 2$	$y = 5.30624$ where $r = 6$
$y = 16.32656$ where $r = 3$	$y = 0.$ where $r = 7$

Let us assume that both girders are so constructed that the unit strain upon the chords is uniform throughout.

Take $C_0 = 552$ pounds = allowed inch strain in compression.

$T_0 = 1,200$ pounds = allowed inch strain in tension.

$B_0 = \frac{552 + 1,200}{2} = 876$ pounds = inch strain in bending.

$E = 1,460,000$ pounds per square inch = modulus of elasticity, all for pine.

Then the total deflection at the centre for the Howe truss, having regard to the sloping end panels, will be:

$$D_c = \frac{B_0}{Eh}\left\{\left(\frac{6a}{7}\right)^2 + 2\left(\frac{a}{7}\right)^2 + 12\left(\frac{a}{7}\right)^2\right\} = \frac{50\,B_0}{Eh}\left(\frac{a}{7}\right)^2$$

$$= \frac{50 \times 876}{1,460,000 \times 12 \times 20} \times \left(\frac{12 \times 100}{7}\right)^2 = 3.6734 \text{ inches.}$$

And at any other point the deflection of the Howe truss will be:

$$D_x = 3.6734 - \frac{B_0}{Eh} x^2$$

D_x	$= 3.6734$ inches when $x =$	0
"	$= 3.5999$ " " " $=$	$a \div 7$
"	$= 3.3795$ " " " $=$	$2\,a \div 7$
"	$= 3.0122$ " " " $=$	$3\,a \div 7$
"	$= 2.4980$ " " " $=$	$4\,a \div 7$
"	$= 2.8367$ " " " $=$	$5\,a \div 7$
"	$= 1.0286$ " " " $=$	$6\,a \div 7$
"	$= 0$ " " " $=$	a

But the deflection of the given parabolic girder at the same points, is :

$$D_x = \frac{aB_0}{Eh}\left\{ 1.3863a - 2.302585\left[(a+x)\,log\,(a+x) + (a-x)\,log\,(a-x) - 2a\,log\,a \right] \right\}$$

"	= 4.9910 inches	where	x = 0
"	= 4.9171 "	"	" = $a \div 7$
"	= 4.6933 "	"	" = $2a \div 7$
"	= 4.3078 "	"	" = $3a \div 7$
"	= 3.7470 "	"	" = $4a \div 7$
"	= 2.9525 "	"	" = $5a \div 7$
"	= 1.8529 "	"	" = $6a \div 7$
"	= 0 "	"	" = a

It is manifest that these two girders will not work together, if they are of the same central height and under the same unit strain. We may harmonize the deflections in some measure, either by increasing the height of the parabola, or diminishing its allowed unit strain.

II. If we increase the central height of the parabola in the ratio of the central deflections just found, viz. $\frac{4.9910}{3.6734}$, we shall have for the augmented heights :

y	= 27.174 feet	where	r = 0
"	= 26.619 "	"	" = 1
"	= 24.956 "	"	" = 2
"	= 22.183 "	"	" = 3
"	= 18.300 "	"	" = 4
"	= 13.310 "	"	" = 5
"	= 7.209 "	"	" = 6
"	= 0 "	"	" = 7
Deflection D_x	= 3.6734 inches	"	x = 0
"	= 3.6190 "	"	" = $a \div 7$
"	= 3.4543 "	"	" = $2a \div 7$
"	= 3.1706 "	"	" = $3a \div 7$
"	= 2.7578 "	"	" = $4a \div 7$
"	= 2.1731 "	"	" = $5a \div 7$
"	= 1.3638 "	"	" = $6a + 7$

From which it appears that even now the deflections of the two girders agree only at the centre and ends of a span : but the difference is small at any point.

III. We may in the following manner vary the unit strain B, in the different panels, so that the deflections at the panel-points may agree. This change of unit strain is, of course, to be made in the parabolic girder, since the Howe truss is supposed to be in place, and we are assisting it by means of the bowstring girder.

The equations to be used for this purpose are :

$$B_r = \frac{\left(\triangle D - \frac{l}{n}\ tan.\ \alpha_{r-1}\right)\ Eh}{2.302585\ a\ \left(a\ log.\ A + \frac{rl}{n}\ log.\ Q\right)} \tag{1}$$

$$tan.\ \alpha_r = tan.\ \alpha_{r-1} + \frac{2.302585\ B_r\ a\ log.\ Q}{Eh} \tag{2}$$

Where $\triangle D^x$	= .0735		x = $a \div 7$
" "	= .2204		" = $2\ a \div 7$
" "	= .3673		" = $3\ a \div 7$
" "	= .5143		" = $4\ a \div 7$
" "	= .6612		" = $5\ a \div 7$
" "	= .8082		" = $6\ a \div 7$
" "	= 1.0285		" = a

α= inclination to horizon of tangent to the elastic curve.

$$A = \frac{n^2 - 4r^2}{n^2-4(r-1)^2}$$

$$Q = \frac{(n + 2\,r)(n - 2\,r + 2)}{(n - 2\,r)(n + 2\,r - 2)}$$

At the centre we have $tan.\ \alpha_{r-1} = 0$; hence $B_r = B_1$ is found from equation (1). With the value of B_1 we find $tan.\ \alpha_r = tan.\ \alpha_1$ by equation (2). Then putting $tan.\ \alpha_1$ in (1), it yields B_2; and with $tan.\ \alpha_1$ and B_2 in equation (2) we get $tan.\ \alpha_r$, and so on.

In the present case,

$B_0 = 876$	pounds per square inch at centre.	
$B_1 = 873.4$	" " " "	$r = 1.$
$B_2 = 836.5$	" " " "	$= 2.$
$B_3 = 765.8$	" " " "	$= 3.$
$B_4 = 659.8$	" " " "	$= 4.$
$B_5 = 529.1$	" " " "	$= 5.$
$B_6 = 317.2$	" " " "	$= 6.$
$B_7 = 231.1$	" " " "	$= 7.$

Therefore, by increasing the size of the chords of the parabolic girder, to conform to these inch-strains, we have the two girders of the same central height, agreeing in their deflections at all panel-points.

IV. Allowing a tension of 10,000 pounds to the square inch of section of vertical iron rods, these rods will be stretched by about .0004 of their length, as shown in the table below.

V. A rise of temperature from the freezing to the boiling point expands wrought iron by .0012 of its length; that is, a change of 1° Fahrenheit, alters the length of a bar of wrought iron by

$$\frac{.0012}{180} = .0000066666$$

of itself. A change of 60° alters the length by .0004 of itself, which is just equal to the change of length due to 10,000 pounds per square inch of section. Hence, if the girders be adjusted at a temperature of 80° Fahrenheit, a cooling to 20° Fahrenheit will contract the iron by just the amount of elongation due to the tension.

VI. The accompanying figure and tabulated results present at a glance the substance of this paper, from which results it is clear that the difference of the deflections of the Howe truss and the parabolic bowstring girder of same height, under the same unit strain, is a greater obstacle to their harmonious working than the combined effects of tension and change of temperature of the iron.

Also, if these two girders are connected with each other so as to form one, the unit strain upon the bow will be less than that upon the truss, nearly in the ratio of their deflections at the centre, when separate and under the same unit strain.

The reader will perceive that in case the original Howe truss is so built that the unit-strain is not uniform throughout its chords, still its deflec-

tion may be determined, and a parabolic arch be formed so that the two will work nearly in harmony.

Panel-point, r	0	1	2	3	4	5	6
Height, ft. y...........	20	19.59	18.37	16.33	13.47	9.80	5.31
Deflection of Howe.....	3.6734	3.5999	3.3795	3.0122	2.4980	1.8367	1.0286
Deflection of parabola.	4.9910	4.9171	4.6933	4.3078	3.7470	2.9525	1.8529
Height of upper parab.	27.174	26.619	24.956	22.183	18.300	13.310	7.209
Deflection of same.....	3.6734	3.6190	3.4543	3.1706	2.7578	2.1731	1.3638
r	0–1	1–2	2–3	3–4	4–5	5–6	6–7
Changed inch-str. Br.	873.4	836.5	765.8	659.8	529.1	317.2	231.1
r	0	1	2	3	4	5	6
Extension of verticals due strain, ins.							
Long verticals..	.1296	.1274	1198	.1065	.0878	.0639	.0346
Truss "	.0960	.0960	.0960	.0960	.0960	.0960	.0960
Short "	.0960	.0940	.0882	.0784	.0647	.0470	.0255
Truss rods expand, ins. from 80° to 100° F...	.0320	.0320	.0320	.0320	.0320	.0320	.0320
Truss rods contract ins. from 80° to 20° F. ..	–.0960	–.0960	–.0960	–.0690	–.0960	–.0960	–.0960
Total elongation of truss rods at 100°....	.1280	.1280	.1280	.1280	.1280	.1280	.1280
Total elongation of parabola rods at 100°....	.1280	.1253	.1174	.1040	.0868	.0627	.0280

PROCEEDINGS.

October 11, 1881:—A regular meeting of the Club was held, Vice-President Col. J. M. Wilson in the chair.

Proposals for active membership in the Club were received from E. H. Harvey, Frank C. Smith and S. H. Curtiss.

The special committee appointed on the resignation of President Charles Paine presented the following preamble and resolutions, which were unanimously adopted:

Whereas, Mr. Charles Paine, on account of removal from the city, has felt compelled to resign the presidency of the Engineers' Club; therefore,

Resolved, That the following minutes be spread upon the records of the Club, and that a copy be sent to Mr. Paine:

The Civil Engineers' Club of Cleveland, O., deeply regrets the necessity which compels the resignation of Mr. Charles Paine, its first President, and recalls with much pleasure and gratitude his active interest in its welfare.

The Club is very largely indebted to Mr. Paine for its organization, and believes that its increase is largely due to his persevering attention to the duties devolving upon him as the executive officer. We, the members, will always hold in agreeable memory his association with us in the work which has placed the Club upon its firm basis, and trust that when he is in our city he will visit our rooms and allow us the privilege of personally expressing our respect for his eminent ability as an engineer and our personal regard for him as a friend and a courteous gentleman.

The Club further desires to express to Mr. Paine its sincere thanks for the valuable donations of books to the library, and its best wishes for him in the duties of the new field to which he has been called.

Col. J. M. Wilson then read a very interesting paper descriptive of the Teredo Navalis, presenting various specimens of its work.

A problem was then taken from the question box and referred to Mr. J. D. Crehore for answer.

On motion, the Club adjourned to meet on the second Tuesday of November.

J. S. Oviatt, Secretary pro tem.

NOVEMBER 8, 1881 :—A regular meeting was held, Vice-President Col. J. M. Wilson in the chair.

Record of last meeting read and approved.

On motion, Messrs. E. H. Harvey, Frank C. Smith and S. H. Curtiss were elected active members.

A communication was read from Ex-President Paine, expressing his interest in the Club, and his intention to visit its rooms whenever possible.

The name of Mr. C. O. Palmer was presented for active membership.

Mr. John Whitelaw, Water-Works Engineer, gave an interesting description of the water supply of Cleveland, describing the effects of the extreme cold of the Winter of 1880–81 ; also of the extreme drouth of the past summer, illustrating his remarks with diagrams.

City Civil Engineer B. F. Morse gave a description of the process of centering the massive stone arches of the Cleveland Viaduct, and of the stone arch on the L. S. & M. S. R. R., at Painesville, O., during their construction.

Mr J. F. Holloway, Superintendent and Engineer of the Cuyahoga Steam Furnace Company, gave a description of the process of constructing large metal castings.

Mr. J. D. Crehore presented a solution of the query taken from the question-box at the last meeting.

On motion the Club adjourned to meet on the second Tuesday in December.

C. H. BURGESS, Secretary.

BOSTON SOCIETY OF CIVIL ENGINEERS.

ORGANIZED 1848.

TRANSACTIONS.

This Society is not responsible as a body for the statements and opinions advanced in any of its publications.

SOME REMARKS ON THE TASTES AND ODORS OF SURFACE WATERS.

BY WM. RIPLEY NICHOLS, MEMBER OF THE SOCIETY.

[Read December 21, 1881.]

As all know, the water supplied to a considerable portion of the City of Boston has recently possessed a very bad taste and odor, the culmination of the trouble being in the early part of November. We are also all aware that the source of the bad taste was located in Farm Pond, and that the cause is supposed by Professor Remsen to be due to the presence of a considerable quantity of a fresh-water sponge.

As to whether the sponge was really the cause of the recent trouble, I cannot express any opinion, for, although the theory is a very plausible one and may easily satisfy a person unfamiliar with water supplies, I do not think that the facts already published are sufficient to enable a specialist to form an opinion without personal investigation, and this I have had no opportunity to make. Nevertheless it is certainly a clue of too great importance to be neglected, and further careful observations are called for in order to see how general a cause it may be.* Of this I will speak later.

Any one who has had occasion to make, or to try to make, positive statements with reference to the various points of interest in connection with the water of public supplies, cannot but be impressed with our lack of sufficient knowledge in a great many directions, and, with reference to the tastes and odors of surface waters, our knowledge is exceedingly fragmentary. The fact is that there are comparatively few water-works, take great and small together, which have in their corps persons who have been *trained to observe*, even if it were possible to persuade those in authority of the worth of observations whose practical fruit may not appear for years. In the larger places, the multitude of the details of the regular work, and especially emergencies which, for a limited time,

* Since the above was written the full text of Professor Remsen's report has been published. See note at end of this paper.

require the undivided attention of those who might otherwise like to carry on special investigations, prevent the accomplishment of as much in this direction as is desirable, or interrupt work already begun. Another reason for the contradictory and fragmentary nature of our information in certain lines is that, when emergencies arise which lead to the calling in of "experts," the decision to call in outside aid is often not made until the difficulty is on the decrease and it has become too late to hope to seek the cause. Moreover, the expert is often expected to formulate an opinion after opportunity for only a cursory examination, without a knowledge of the past history of the case, and with such information only of the earlier stages of the trouble as can be picked up from ordinary workmen, who are untrustworthy observers.

What is really needed is that some person trained to scientific observation, with ample means and with plenty of interest in the subject, should locate himself with assistants in the neighborhood of the impounding reservoirs of an extensive water-works, such as those of the city of Boston, for example, and devote himself for, say five years, to the collection and comparison of daily observations in various directions. Of course, self-recording apparatus would be called into play, visits to other localities would be made, earlier observations would be collected, etc. I do not propose to sketch a plan of the particular directions in which these investigations should extend, but I do not know to what problem of applied science a person, not too eager for sudden fame, could better devote say five years of work and $4,000 or $5,000 a year in money. I would not in any way depreciate the many valuable investigations which have been made by persons connected with our own and other water-works, but these would have increased value in case of such an extended investigation, and many fragments now of no apparent use would find a place in the growing whole. Of course, in the above investigation, it would not be necessary that the time and the money should come from the same individual—the money might come from the State—but it would be, to my mind, essential that the person furnishing the time should have the enthusiasm which would lead him to furnish the money if he had it!

The disadvantages of the fragmentary investigations which, in some cases, give us all the knowledge we possess, are well illustrated when we come to try to put together what we know about the odors and tastes which occur in surface waters, especially in ponds and reservoirs.

In the first place, we may note that, to average persons, tastes and odors are very closely related; with the nostrils closed, what was thought quite offensive to the taste is sometimes scarcely noticed, and the expression, "this tastes just as such and such a thing smells," although it seems absurd, really indicates the operation of the ordinary mind. Moreover, as Piesse says:* "To the unlearned nose all odors are alike," and even the better class of persons, not specially trained to such observations, cannot make nice distinctions of odors and tastes; the same bad water will be described differently by different persons, and it is often possible to influence the imagination so that a bad-tasting water is pronounced tasteless, and a tasteless water appears highly flavored. I

* The Art of Perfumery, 2d American edition, p. 40.

have known persons to be persuaded into the efficacy of some purifying process which took away taste only in the imagination of the taster. Probably most have eaten so-called "mock oysters," and know how closely the taste and the appetizing flavor of the oyster can be imitated with green corn.

I mention these facts in order to assert with emphasis that it does not follow that, because on two different occasions a similar taste is reported, the cause must necessarily be the same, and this is much more the case when the similarity consists in the description of different persons. The nicety of the taste and smell of wine merchants, tea-tasters, and other specialists, shows us what might possibly be attained by water-experts. Of the more common perfumes, Piesse even makes a gamut in both treble and bass, with flats and sharps, and maintains that he can assign "at smell" the key corresponding to each of the numerous odors of a chemical laboratory. But, at the same time, he asserts that "from the odors already known, we may produce, by uniting them in proper proportion, the smell of almost any flower, except jasmine;" so that an untrained person would not know whether he was dealing with a simple or with a mixed odor. I suppose there must be an analogy in taste. The so-called "cucumber" taste, or, at any rate, what *I* call a cucumber taste,* is so marked and well-characterized that I have been inclined to consider it *sui generis*, but still, for all that any one knows, it may be produced by chemical action upon various substances, and it may be a mixed taste. It seems to be a secondary product of some sort, for I have again and again, at a time when there was no complaint, drawn water which seemed to be tasteless, and which was as clear as could be obtained by the use of a Grant's filter, but which, after standing in a current of cool air, or even in an ordinary room, soon developed a most decided cucumber taste; I have not been able to bring about this change by the use of chemical reagents. Mr. Fteley has told me that it is, at least sometimes, possible by adding common salt to water possessing the cucumber taste to develop a decided oily flavor. This observation I do not attempt to explain. It is certainly curious, and suggests to me a line of experiment which I regret that I have not been able to follow up.

In the case of surface waters we have to do simply with the odors and tastes which are produced by organic substances, living or dead, and a complete mastery of the subject would call for a knowledge of the odors and tastes communicated to water under different circumstances by all the various plants and animals which grow and die in running and stored water. Some such investigations have been made, but not much has been published from the present point of view. When endeavoring to produce artificially the "cucumber" taste in 1876, I made some experiments on portions of the different land and aquatic plants which grew in and near the Bradlee Basin, and more recently Prof. W. H. Brewer, of Yale College, has made numerous experiments, especially on the heart and sap

* There is great looseness in the use which has been made of late years of the term "cucumber" in this connection. Any particularly bad taste is likely to be thus designated, and water-supplies are reported to be, or to have been, afflicted with the "cucumber taste," when the taste has resembled that of cucumbers as little as chalk resembles cheese.

wood of various trees, but the results have been published, as far as I know, only in part.*

The worst smell that I obtained was from allowing the seed-bearing portions of a species of *Potamogeton* to decay in water, and Professor Brewer has informed me that he obtained a very *fishy* odor from the decay in water of the leaf-stalks of a pickerel-weed, *Pontederia cordata*, which grows on the margins of the pond from which New Haven receives its supply (Whitney Lake). Probably most know that water in which flax is "retted"† becomes very offensive, as also does the waste water from starch factories;‡ it would, indeed, be difficult in some of these cases to persuade a person inexperienced in such matters that the offense did not proceed from the decay of animal matter.

While the odors and tastes obtained from different plants differ from each other, in a stream or pond where the volume of water is comparatively large and the opportunity for aeration is great, the various tastes seem to *blend* into a more or less marked marshy or pondy flavor. Sometimes, even in large bodies of water, a distinctive taste is noticed: thus, in the fall of the year, the water of our ponds and lakes which are surrounded by woods acquires more of a bitter or astringent taste, which is to be referred to the dead leaves at that season most abundant.

A word or two may be in place with reference to the action of fresh water upon vegetable matter in its bearing upon impounding reservoirs.

When a recently felled tree is exposed to the action of the water, or when bushes or even grass and weeds are killed by being flooded with water, the sap and more soluble matters are leached out and putrefy, or, in the presence of much air, undergo other forms of decomposition. This action will take place, no matter under what depth of water the vegetable matter may be placed, but the effect will be less marked as the amount and motion of the water is greater.

After the more soluble portions are extracted, the subsequent decay proceeds with extreme slowness, provided the remaining cellulose or woody fibre is kept continually covered with water, but alternate exposure to air and water soon causes decay, as every one knows. In a natural or artificial reservoir the inevitable variations of level are very disadvantageous. As the level is lowered, those aquatic plants which grow in shallow water die, and if the water rises after only a short interval it becomes impregnated with the product of their decay; if a considerable interval elapses, land plants grow upon the exposed surface, and, being drowned by the rising waters, tend to its contamination in the same manner.

The substances which form the most offensive part of the soluble vegetable matter are *albuminous* in character, and the chemical effect on the water is to increase the amount of what is designated as "albuminoid ammonia;" that is, they contain nitrogen, which, under the analytical treatment, is evolved and measured as ammonia. It is unfortunately impossible by analytical means to distinguish whether this "albuminoid

* Brewer, W. H. On Rotting Wood. American Public Health Association, Vol. v., p. 66.

† In this connection see Reichardt, E., "Schädliche Wirkung des Rostwassers von Flachs und Hanf für die Fischzucht." Arch. d. Pharm., ccxix., Heft 1, 1881.

‡ See, for example, Vohl, *Dingler's polytechn. Journal*, clxxxii., 325.

ammonia" is to be ascribed, in any given case, to vegetable or to animal origin. No doubt the excrement of fishes, their dead bodies so far as they are not consumed by their living comrades and by the animalcules, the bodies of the animalcules themselves, add to the nitrogenous organic matter in our surface waters, but their presence is not necessary to account for bad odors, for, as we have seen, under certain circumstances as great offense may proceed from vegetable as from animal sources. As a rule, in waters not contaminated by sewage, the animal matter forms only a trifling proportion of the entire organic matter, but the recent investigaton of Professor Remsen shows that in some instances the animal matter (as from sponges) may be appreciable and of practical importance.

When vegetable matter decays in moist soil, it is converted into a brown or black substance generally known as *humus*: this is really a mixture of a number of different bodies, and from it chemists have isolated a variety of substances such as humic acid and humin, ulmic acid and ulmin.* The acids of the humus by oxidation undergo chemical change, to be sure, being converted into crenic and apocrenic acids, which, or rather the salts of which, are found in surface waters; but when the vegetable matter is thoroughly "humified," as in the case of peat, it exerts apparently no bad effect on the water except by giving it a brown color and a somewhat earthy taste.

If surface waters containing vegetable matter be confined in vessels or tanks, the dissolved organic matter undergoes chemical change; the water becomes less strongly colored, and a sediment deposits at the bottom of the vessel. This change is frequently spoken of as "fermentation;" but it is doubtful whether the term rightly characterizes the nature of the change.

There is one condition under which organic matter may decay and give rise indirectly to considerable offence. Occasionally the odor of sulphuretted hydrogen becomes very noticeable, and the water acquires therefrom a foul taste. The most marked instance of this that I ever witnessed was in the Basin No. 3 of the Sudbury River Supply, the summer after it was first filled. The whole mass of water in the basin was permeated with the odor, which was so strong on the leeward side of the pond as to incommode the passers-by. The odor was not that of pure sulphuretted hydrogen as prepared in the laboratory, and the gas was no doubt accompanied by other chemical products. The water drawn from the depths of the pond had the odor of an antiquated privy. The presence of sulphuretted hydrogen was made very manifest by suspending in the gate-house cloths wet with a solution of acetate of lead; these became yellowish-red, and finally jet black, owing to the formation of sulphide of lead.

The formation of the sulphuretted hydrogen is readily explained. The flooding of the basin started the decay of a large quantity of organic matter; this taking place in the presence of the sulph*ates* contained in the water changed them into sulph*ides*, and from these sulphides thus formed sulphuretted hydrogen is liberated by the acid products of decay. This same change takes place to a less degree in almost all ponds and reservoirs. The gas is formed, however, mainly at the bottom, and as it

*For a résumé of the investigations on the composition of humus, see Julien, A. A. Proc. Amer. Assoc., xxviii. (1879), p. 313 and foll.

diffuses upwards and mixes with the overlying water it comes into contact with the oxygen in the water and is decomposed. The sulphur is set free and sinks to the bottom or in a very finely divided state flows off with the water. In salt or brackish water which receives sewage, these changes take place on a much greater scale. A while ago I examined a number of samples of mud from the lower part of the Charles River. In all cases, sulphur in considerable quantity could be extracted from the mud by the use of proper solvents.* Even the mud from such a reservoir as the Walnut Hill Reservoir of the Mystic works, which was cleared out in 1878, was found to give off sulphuretted hydrogen when boiled, at the rate of 0.34 of a cubic inch to each cubic foot of the mud, and each cubic foot contained also sulphides enough to give off 0.88 cubic inches of sulphuretted hydrogen when treated with acid.†

Beside the tastes and odors which come from the decay or decomposition of the ordinary vegetable matter, stored surface water is liable to other tastes and odors which are due to the presence and more especially to the decay of *algæ*—fresh water sea-weeds. It is not a great many years since these minute plants were first recognized as causing trouble in water supplies, but now they are held by some to be the source of foul odors and tastes even when no algæ can be discovered! There is no doubt that they are in many cases the real cause. When fresh and growing, unless present in considerable quantity, they give scarcely any taste or odor; if present in larger quantities, or if collected on a filter, they have an odor which seems to me most like that of green grass which has been macerated in water for a short time, or which has been masticated somewhat. This matter of algæ has been discussed quite fully by Dr. Farlow, in a recent report of the State Board of Health, Lunacy and Charity.‡ All surface waters contain *algæ*, such as *desmids* and *diatoms*; these, however, do not multiply to such an extent as to cause trouble. The troublesome species belong, almost all, to the family of *Nostocs*, and of these the number which have been known to produce difficulty is small; this may, of course, be due in part to imperfect observation. A single species each of *Cœlosphærium* and *Clathrocystis*, two or more of *Anabœna* and one of *Sphærozyga*, I have observed in considerable quantities in this neighborhood. In very pure waters and in old and clean ponds these plants flourish, but they seem to grow more abundantly in water containing mud and vegetable extractive matter, as in newly filled reservoirs, so that while immunity from their presence cannot be guaranteed in the case of any pond, they may with some certainty be looked for in dirty and especially in shallow ponds. Thus, I do not know that any complaint has ever been made at Salem of the Wenham Lake water which could be laid to algæ, but I have observed them in summer in considerable abundance scattered through the waters of the lake. A warm temperature and shallow water are perhaps of even more importance than the products of decay of higher plants, for all sur-

* Eighth Annual Report Boston City Board of Health. (1879–80), pp. 12–18.

† Third Annual Report of the Boston Water Board. City Document No. 79, 1879, p. 43.

‡ First annual report of the State Board of Health, Lunacy and Charity. Supplement (Dep't of Health), pp. 129–152. 2 plates.

face waters contain the ammoniacal and mineral salts necessary for the growth of the algæ.

The odors (and tastes) from the algæ are quite various. Mr. Fteley calls it a *musty* odor; at Albany it was spoken of as a *musty* and as a *cucumber* odor; at Springfield (Ludlow Reservoir), the first summer after the reservoir was filled, there was a most distinct odor of *green corn*, perceptible for, I should say, a quarter of a mile from the pond on the leeward side. The pond was covered with a slime of algæ, some of them decaying, and the same marked odor was noticed at the water troughs along the line of the aqueduct.

When, under the excessive heat of summer, the algæ are collected in masses and begin to decay, a most abominable *pig-pen* or *horse-pond* odor is sometimes noticed in the ponds: but, as far as my experience goes, this is seldom noticed in the water drawn from the service pipes, although a foul odor similar to that common in "dead-ends" does occur when water containing the algæ stagnates in the pipes.

In the case of a bad condition of the water arising from the decay of an unusual amount of animal or vegetable matter on the bottom or sides of the reservoir, or from the presence of algæ, the water is ordinarily characterized by an abnormal amount of soluble organic matter which shows itself in the common method of analysis as "albuminoid ammonia," or in the Frankland method as "organic carbon" and "organic nitrogen." But, in order to judge whether the amount is abnormal or not, it is necessary to have an extended series of analyses, and this is seldom at hand. The effect of algæ may be well seen by a study of the weekly analyses of the Springfield water for the years 1876 and 1877, and of the Mystic during 1879, as shown in the respective water reports.*

The value of such extended *series* of determinations hardly admits of discussion, and the value would be enhanced by accompanying careful microscopic examination. For instance, if weekly or more frequent microscopic examination of the water from the various sources of the Boston supply had been made, it seems to me almost certain that an abnormal amount of sponge-spicules would have been found in the water flowing from Farm Pond—if not in that received in the city—provided there really was enough sponge in the state of decay to be the cause of the recent trouble.

I would here speak briefly of the experience at Poughkeepsie, N. Y., where the sequence of cause and effect is very marked. Here the Hudson River water was pumped on to filter-beds, thence, after filtration, into a small uncovered reservoir. In summer, after the temperature of the water reached 70° F., an alga, one of the *oscillariaceæ*, developed in the shallow water on the beds and in the reservoir, and by its death and decay in the pipes caused much trouble. The trouble occurred every summer until the following method of procedure was adopted by Mr. The. W. Davis, the then Superintendent. As soon as the temperature of the river water approached 70°, careful watch was kept on the temperature and on the quality of the water delivered. As soon as the taste

* See Annual Reports of the Water Commissioners of the City of Springfield (Mass.), 1877 and 1878. Also, First Annual Report of Massachusetts State Board of Health, Lunacy and Charity. Supp., pages, 119, 120.

or odor was noticed in the city, the reservoir was shut off and the water pumped directly from the river into the mains. In this way all trouble was avoided and there were no complaints. I make no remark as to the value of the filter-beds during this period, but the cause of the specific trouble was thus quite conclusively proved.

Besides the tastes and odors which may with reasonable certainty be ascribed to the growth or decay of organized beings, there have been certain conditions of the water in the case of many water supplies which are very enigmatical, and for which no satisfactory explanation has been offered. I refer to our own "cucumber" taste of 1875–6, and to certain other tastes "of the same order," if I may use the expression. The tastes occur when the water is of its ordinary purity and in waters naturally pure. Some have maintained that the tastes ought to be due to the presence or to some peculiar condition of the algæ, but as it is impossible to discover any unusual amount or condition of those algæ, which are, so far as we know, harmless, and which are always present, and as none of those algæ which are known to produce bad tastes and odors are found, it is rather difficult to accept this explanation. Since Professor Remsen has found reason to believe that the recent condition of the water in Farm Pond is due in part, at any rate, to the decay of a sponge, it has been suggested that we have here the cause of the various difficulties heretofore unexplained, and Professor Remsen himself seems to imply that this must have been the cause of our trouble in 1875–6, and of the Baltimore trouble, which he himself investigated, and he seems further to imply that the probable reason why the sponge has not been before this identified with the trouble is that investigations have been begun too late.

It is impossible, of course, to go back and reinvestigate troubles of the past, and the best that we can do is to watch carefully in the future; but we can consider the bearing of the "sponge theory" on cases where we have the results of personal observations or sufficiently explicit records. First, however, a word or two about the sponge itself. It is not uncommon in ponds and reservoirs, such as are used for water supply, and grows sometimes even in the masonry conduits. For instance, about three years ago, Mr. Wm. B. Sherman, Superintendent of the New Bedford water-works, sent me some specimens of a *spongilla* taken from the conduit of their works. The water flows at the rate of a trifle more than a mile an hour, and fills the conduit to about two-thirds of its depth. The sponge is most abundant near the pond end, say for the first mile, but occurs in patches further down the line. The conduit is perfectly dark.

The sponge has a sufficiently marked odor, and would no doubt communicate a peculiar, if not disagreeable, quality to a limited amount of water, but it has always been supposed (and I have yet to see evidence that the opinion is wrong) that, in a pond suited for water supply, the amount would be too small to affect the water as a whole so long as the sponge was in a normal condition. It would seem then that if the sponge causes trouble, it must be by decay or as a result of some abnormal condition, and this we might suppose also from the fact that the troubles occur only at intervals and are of limited duration.

The next point is as to when the trouble would be most likely to occur: or, in other words, what cases should we naturally investigate first.

A few years ago, in the interest of the New York Board of Health, Dr. Elwyn Waller brought together as many details as could be obtained with reference to distressed water-supplies all over the United States.* Selecting from these such as afford sufficient details to serve my purpose, rejecting those where the trouble is from "dead-ends," etc., I find that of thirty cases, twenty places have had trouble in spring and summer, and five places have had trouble in fall and winter only, while five places report trouble at all seasons. Now, in the case of a number of the places where the trouble comes in spring and summer, I feel sure, from personal knowledge, that the trouble is due, partly, at any rate, to the presence of algæ, although I am quite willing to admit that the algæ may not be in all cases considered the ultimate or the only cause of the difficulty. The fewer cases which are recorded only in the fall and winter, and where no algæ have been observed during the preceding summer, are more enigmatical. Although algæ, and indeed the noxious algæ, are found to a certain extent at all seasons, we should not look for their sudden appearance after the height of the summer, and when the water is cooling off. Here, then, is a chance for the application of the sponge theory. Moreover, it is not unreasonable to suppose that the approach of cold weather, especially if there should be a sudden fall of temperature, might interfere with the growth, and perhaps cause the sudden death, of the sponges, as excessive and sudden warm weather causes the death of algæ when accumulated on the surface of the ponds.

Let us then see how the sponge theory will apply to some of these cases.

First, I will take our own case of 1875–6, which most will remember. This began in the latter part of October and appeared in the city, at least in my laboratory, as a decided "cucumber" taste, but in other parts of the city it was called a fishy taste. The taste seems to have begun *in the pipes;* at any rate, when the water began to taste strongly in the city the taste was not to be noticed in the lake or in the reservoirs. On October 26, the Bradlee basin, which was the only one affected, was reported by officials of the water-board as free from the taste, but on October 27, when I first began my observations, it was permeated throughout by the taste; thus, in not more than 24 hours the "something" had diffused itself through the entire basin. If now we appeal to the sponges, we notice that while sponges do grow in conduits, undoubtedly, we do not know of their being found attached to the surface of iron pipes full of water flowing rapidly; and doubt as to their being able, or at any rate likely, to thus grow, has been expressed by naturalists. Again, it is difficult to see how any inanimate substance, either suspended or in solution, or any organism without power of locomotion, could force itself, contrary to the current, and spread, in so short a time, over the extent of the basin. If we admit that the observation may have been incorrect, and that the taste really originated in the basin itself, then if it came from the sponges we should expect at least two things: first, that fragments of the sponge

* Report on Croton Water, by Elwyn Waller, Ph. D., Chemist to the Health Department. Pph. 8vo. pp. 46. 1 plate. New York, 1881.

would be found on the screens at the gate-house and in the samples of sediment from the bottom; and, second, that the "albuminoid ammonia" would run abnormally high; probably also, thirdly, the "albuminoid ammonia" in the *unfiltered* water would run considerably above that in the *filtered* water, as Remsen found in Farm Pond. The truth is, however, that no fragments of sponge were noticed on the screens by either Mr. Burgess or Dr. Farlow or by myself. Moreover, before the basin was shut off from the supply I had cotton cloths stretched over the screen, and these cloths showed no such attached fragments of sponge as would quite certainly be brought against them if there was much decayed sponge in the water. In respect to the "albuminoid ammonia," and in other chemical respects, there was no recognizable difference between the water while the taste lasted and for some months afterward, although the amount was above the average for the entire year following; moreover, there was only a slight difference between the filtered and unfiltered water,* less, indeed, than there was after the trouble was over. For these reasons I cannot help feeling that there *no proof whatever* that sponges were the cause in 1875–6, and, in spite of the various *theories* held then and now, I continue to state that no assignable *cause* was discovered.

The next instance that I would call to your attention is that of New London, Conn. Here the water is taken from a reservoir of some 225 acres area, which was made by raising a natural pond. While in some places the water is shallow, it is generally at least 12 or 15 feet deep, and in some places as much as 50 feet deep. The lake was filled in 1872 and gave no trouble until, in the latter part of October, 1879, a disagreeable odor began to be noticed; and at the time of my visit, December 20, it was very marked throughout the pond. The odor was more noticeable than the taste, and was described as "fishy." This did not seem to me to describe it satisfactorily, but I cannot suggest any better term. There being no series of previous chemical examinations, it was impossible to say whether there was anything abnormal about the water in this respect, but the water was very pure indeed compared with other waters, and even samples taken from the bottom, at depths of 25 and 40 feet, showed very little color and contained only a very small amount of organic matter. From the nature of the banks, and from what I could learn of the character of the bottom and of the amount of shallow water, I do not believe that any one would suggest loam or decaying vegetation as the cause, and microscopic examination ruled out the algæ. There were more cyclopses than are usually found in the water, but there is no reason to suppose that they caused the trouble, as they are often equally abundant in untroubled water, and here they presented no abnormal appearance. I did not look particularly for sponges, of course, but I examined the screens as usual, and my attention was not attracted to anything of the kind, as I think it would have been had there been any-

*Among the samples examined there was one where the "albuminoid ammonia" of the unfiltered water considerably exceeded that of the filtered water. As, however, this difference did not appear in any of the other samples taken at about the same time and at other times during the trouble, it was probably due to some accidental and unknown circumstance.

thing there. As I did not visit the pond until about two months after the trouble began, the cause may have passed away. It has seemed to me that this is a most excellent reservoir on which to test the applicability of the sponge theory; and I have reason to believe that, if the New Londoners are unfortunate enough to have a recurrence of the trouble, the sponges will be found if present.

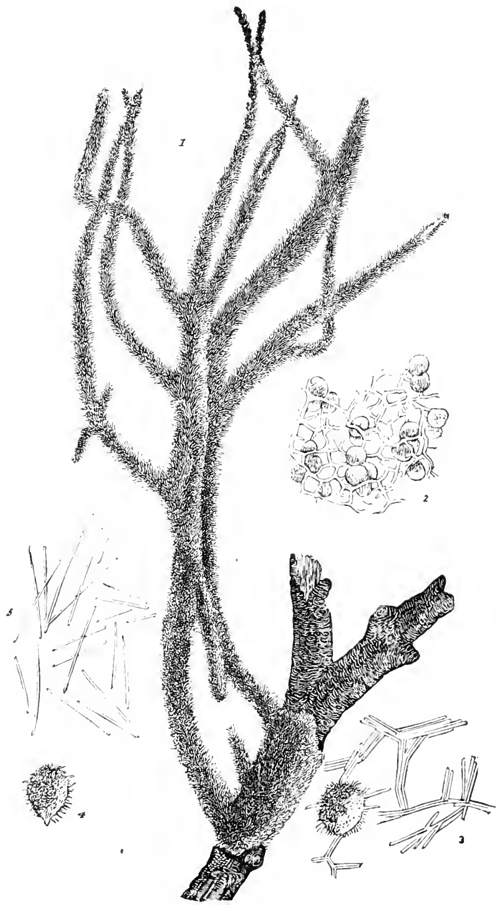
In some respects parallel to the experience of New London, is that of Holyoke, Mass., the trouble beginning in October, 1875, and lasting until March 30, 1876; and here, too, the odor was more marked than the taste. In this case there was a good deal of marshy land surrounding the ponds, and the bottom had been recently disturbed by the building of a dyke to cut off a portion of the marsh. Some ascribed the trouble to this cause; but the amount of organic matter in solution was quite small. On account of the extreme cold of the day on which I visited the pond, the examination of the surroundings was not very satisfactory. At the present moment, I cannot lay my hand on any notes of the case, and do not remember whether the screens were so arranged as to admit of examination. A microscopical examination of a sample of the water itself failed to show any algæ or fragments of sponge, or anything else suspicious.

In Keene, N. H., the water supply is taken from a storage reservoir formed by raising a small natural pond called "Goose Pond." The flowage area is 51½ acres, and the recently flowed portion was wood and pasture land, and was prepared by cutting off the trees and brush close to the ground; the roots were not removed. The water was first used in 1869. In the summer of 1871 there was a fish epidemic to which a bad taste then occurring was ascribed, but no other trouble in summer had occurred up to 1875. Each winter, however, in January, February or March, for a few weeks, an unpleasant *fishy* taste appeared. I visited the reservoir January 29, 1876, at which time the pond was covered with ice. Here the water at the top of the pond was more colored, more turbid, and on analysis showed more organic matter than the bottom water; the latter was, in fact, tasteless. The character of the pond was such that it might be expected to be favorable to growth of sponges; but no direct evidence of their presence was found either on the screens or in the water.

I have mentioned these few cases, not because I do not think that all sources of water supply ought to be carefully watched, but because it seems to me that such cases as these are the very ones where, in the absence of other plausible explanation, the sponge theory would be most likely to be called upon to do duty without adequate proof—and adequate proof there certainly is not.

It is out of the question to expect that in the smaller places chemical and microscopical examinations should be made at frequent intervals; but careful observations of the screens and of the surfaces exposed at low water can certainly be made, and fragments of sponge if occuring in any quantity on the screens would probably attract the attention of anyone looking for them by their general appearance. The sponge which occurs in the Boston water supply is, according to Prof. Hyatt, the *spongilla lacustris*, but the accompanying cut of the *spongilla fluviatilis* will

give an idea of the general appearance.* The details are somewhat unsatisfactory. No. 2 represents the winter buds held in the mass of spicules: No. 3. a portion of the same enlarged; No. 4. one of the winter buds by which the animal is propagated. and No. 5 the spicules. The sponge is harsh to the touch and with a good lens something of its structure may



SPONGILLA FLUVIATILIS.

be made out: for confirmation, however, it is well to burn off a little on a fragment of mica, moisten with water (or better, with acid, muriatic acid or dilute *aqua fortis*) and examine with a good lens or a low-power microscope (say from 50 to 100 diameters) for the spicules.

[NOTE.—Professor Remsen's report, alluded to above, occurs in the Report of

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* This cut, from Johnston's British Sponges was prepared to accompany an article in the Boston *Medical and Surgical Journal*, Dec. 1, 1881. Houghton, Mifflin & Co., Publishers.

the Joint Standing Committee on Water on the Impurity of the Water Supply. —City Document 143, 1881. The evidence is very strong that the sponge did cause at least part of the trouble in this particular case. In stating the results of the chemical analyses, it is to be regretted that Professor Remsen reports in "Parts per 1,000,000," as it is the almost universal custom in this neighborhood to use "Parts in 100,000," and the very numerous analyses published of late years in the reports of the State Board of Health and of the Water Board have been stated in this way.]

DISCUSSION.

MR. DESMOND FITZ GERALD, at the request of the President, gave a brief account of the recent bad taste in the Farm Pond water. He first described the location of the pond with reference to the Sudbury River supply, and drew attention to the fact that from its position as the last link in the system all the water taken from the basins above was drawn through the pond, thus changing a good proportion of its volume daily. Where the water was drawn off it was found that a very small proportion of the bottom was covered with the sponge, for a guess about $\frac{1}{10}$ of the whole area, and this was confined to the rocky points and islands. In the mud and sand no sponge was found except in a few places immediately adjacent to the rocky portions, and which had evidently washed over. The hold of the sponge on the rocks seemed to be very feeble, so much so that it was with great difficulty a specimen could be secured. This was exhibited to the members, and attention was called to the fact that the plate accompanying Professor Remsen's report did not represent correctly the method of growth, which seemed to be by clinging to the rock wherever it accidentally touched, and in the same way to other portions of the spongy growth wherever it happened to cross. Several other specimens were exhibited, preserved in alcohol, showing this tendency. Mr. Fitz Gerald proceeded to describe Lake Cochituate and the appearance of the cucumber taste in that body of water, also the Chestnut Hill and Brookline reservoirs, and the growth of sponge on the interior of the Cochituate Aqueduct.

He said the sponge theory explained to his mind a great many phenomena connected with the taste which had always been a mystery heretofore, and expressed the belief that the sponge would yet be found growing in the large mains and in Lake Cochituate.* He said that it was not a fact that the velocity in the pipes was so tremendous. Pipes were generally so designed that the velocity should not exceed from two to three feet per second. In regard to the way in which the sponge affected the water, Mr. Fitz Gerald said that he believed it was not by a process of decay that the cucumber odor was emitted; although that, of course, would account for the abnormal quantity of albuminoid ammonia. He had tried the experiment of putting perfectly fresh sponge in some well water, and in about a quarter of an hour the water had become impregnated with the cucumber flavor; which, however, was entirely lost in the course of twenty-four hours. Mr. Fitz Gerald acknowledged that there were some difficulties in accepting fully the sponge theory, but at present he was disposed to agree with Professor Remsen. Further investigations and experiments would of course be made as opportunity offered.

* The winter spores of the sponge have since been found in Lake Cochituate.

PROCEEDINGS.

DECEMBER 21, 1881:—A regular meeting of the Society was held at 7.30 P. M., President Doane in the chair, and nineteen members present.

The record of the last meeting was read and approved.

The government was authorized to renew the subscriptions of the Society to the periodicals taken during the past year.

Mr. C. W. Kettell was elected Librarian to fill a vacancy.

Mr. A. Fteley was elected a member of the Committee on Metric System, and Mr. Wm. H. Bradley a member of the Committee on Class-List of Engineering in the Public Library.

The question of changing the night and place of holding the meetings of the Society was after a short discussion referred to the government, to report at the next meeting.

Mr. George F. Swain was proposed for membership by Professors R. H. Richards and G. L. Vose.

The Secretary read a paper by Prof. Wm. Ripley Nichols on "Tastes and Odors of Surface Waters," and Mr. Desmond Fitz Gerald described the recent trouble in Sudbury River water and gave an account of discovery and removal of the fresh-water sponges which are believed to have caused bad taste.

Prof. Wm. Watson read a paper describing the apparatus used by the Paris engineers to determine the coefficient of attrition of paving stones and road metal.

[*Adjourned.*] S. E. TINKHAM, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

ORGANIZED 1868.

TRANSACTIONS.

GRAPHICAL METHOD OF STUDYING EFFICIENCY OF WATER DISTRIBUTION SYSTEMS AND PERFORMANCE OF FIRE ENGINES, AS ILLUSTRATED BY THE BURNING OF THE COLLIER LEAD AND OIL WORKS, ST. LOUIS, MO.

BY M. L. HOLMAN, MEMBER OF CLUB.

[Read November 14, 1881.]

The burning of the Collier Lead and Oil Works and some adjacent buildings situated on the block between Ninth and Tenth streets and Clark avenue and Walnut street, furnished material for considerable discussion, and many different opinions have been expressed in regard to the supply of water and the efficiency of the distribution system of water pipes in this locality. It seemed that a study of the supply would be of interest to some of the members of the Club, and for this reason only was the work undertaken. The graphical features are brought forward on account of their simplicity and facility of application to similar cases.

The location and sizes of the different pipes in the vicinity of the fire are shown on the plan. The primary system, as it may be called, consists of a 20-inch pipe on Fourteenth street, a 20-inch pipe on Seventh street, a 15-inch pipe on Pine street and a 15-inch pipe on Clark avenue. These pipes are connected at the intersections of Seventh street with Pine street and Clark avenue, and Fourteenth street with Pine street and Clark avenue. The supplies to these pipes beyond the connections are independent of each other, and by reference to the pipe map of the city will be found ample for any demand that can be made upon them. The secondary system is made up of 4-inch, 6-inch and 10-inch pipes connected to the large pipes and to each other.

The locations of the engines in use are also shown on the plan, and we see that the supply to the engines at Tenth and Chestnut streets, Tenth and Spruce streets, Eighth and Clark avenue and Seventh and Walnut streets, is in a greater measure independent of the supply to the remaining engines, and appears to be ample. The supply to the remaining engines is more complex, as the pipes are connected to each other, and the question of supply will be confined to these engines.

The first step is to find the probable amount of water that each engine was delivering on the fire. To do this it is assumed that the engines were all in good order, that the hose was well laid out on the shortest route to nearest point of the fire, and that smooth nozzles of 1⅜-inch diameter were used.

The only authority at hand on this subject is a book by Geo. A. Ellis, and is entitled "Work done by and Power Required for Five Streams, as Determined by Experiments made in the Springfield Fire Department by Chief Engineer A. P. Leshure."

Diagram B is a graphical representation of some of the tables of this book, and is used for estimating the quantities of water thrown by each engine.

The quantities represented on the diagram are:

1. Quantity of water per minute in U. S. gallons.
2. Friction loss of pressure in pounds per square inch in 2½-inch rubber hose for lengths up to 1,000 feet.
3. Effective pressure necessary on smooth nozzles from 1-inch to 1⅜-inch diameter.
4. Vertical distances reached by jets.
5. Horizontal distances reached by jets.

The sum of Nos. 2 and 3 for any particular case gives the pressure necessary at hydrant or steamer.

Quantities of water from 60 to 400 U. S. gallons per minute are represented by distances on line AB from A to the right.

The loss by friction of water in hose in pounds per square inch is plotted as ordinates from AB upwards or towards the top of the diagram. The length of hose is marked on the curves.

The effective pressures necessary on nozzles are plotted as ordinates from AB towards the bottom of the diagram. The curves are marked with the size of the nozzle to which they correspond.

The distance along the ordinate, through the point on AB (corresponding to a given quantity of water per minute), from the curve above AB (representing the length of hose used) to the curve below AB (representing the nozzle used), represents the total pressure necessary at the hydrant or steamer to discharge the given quantity of water.

The vertical distances reached by jets are shown by broken lines below AB, and the corresponding heights are marked to the right.

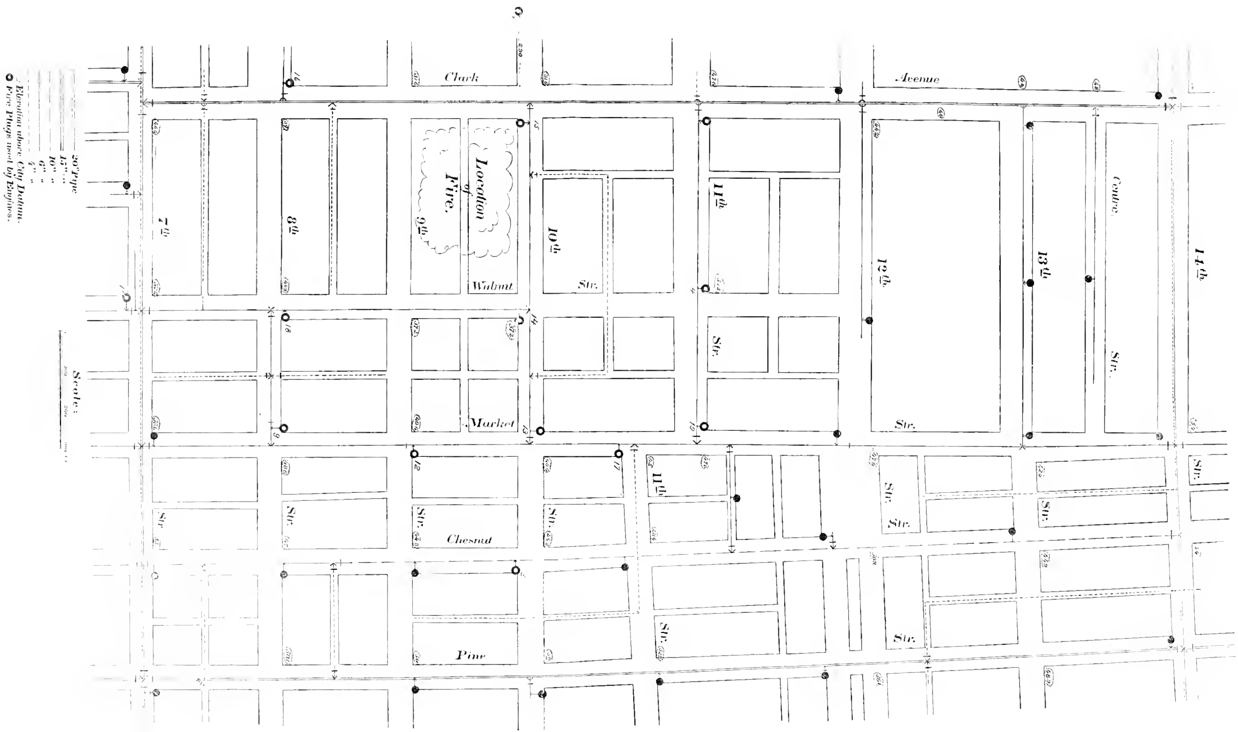
The horizontal distances reached by jets are represented by full lines, and the distances are marked to the left.

For further particulars see example on diagram.

The following are the quantities estimated for each engine:

Number of engine.	Location.	U. S. gallons of water thrown per minute.
1.	Eleventh street and Clark avenue	300
4.	Eleventh street and Walnut street	335
19.	Eleventh street and Market street (west)	265
17.	Eleventh street and Market street (east)	265
15.	Tenth street and Clark avenue	700
14.	Tenth street and Walnut street	380
13.	Tenth street and Market street	300
18.	Eighth street and Walnut street	300
9.	Eighth street and Market street	265
12.	Ninth street and Market street	265

The above estimates, with the exception of No. 15, are based on the



Clark
Avenue
Location of Fire.
7th
8th
9th
10th
11th
12th
13th
14th
Walnut
Str.
Market
Str.
Chesnut
Str.
Pine
Centre
Str.
20" Pipe
Elevation above City Datum.
Fire Plugs used by Engines.
Scale:

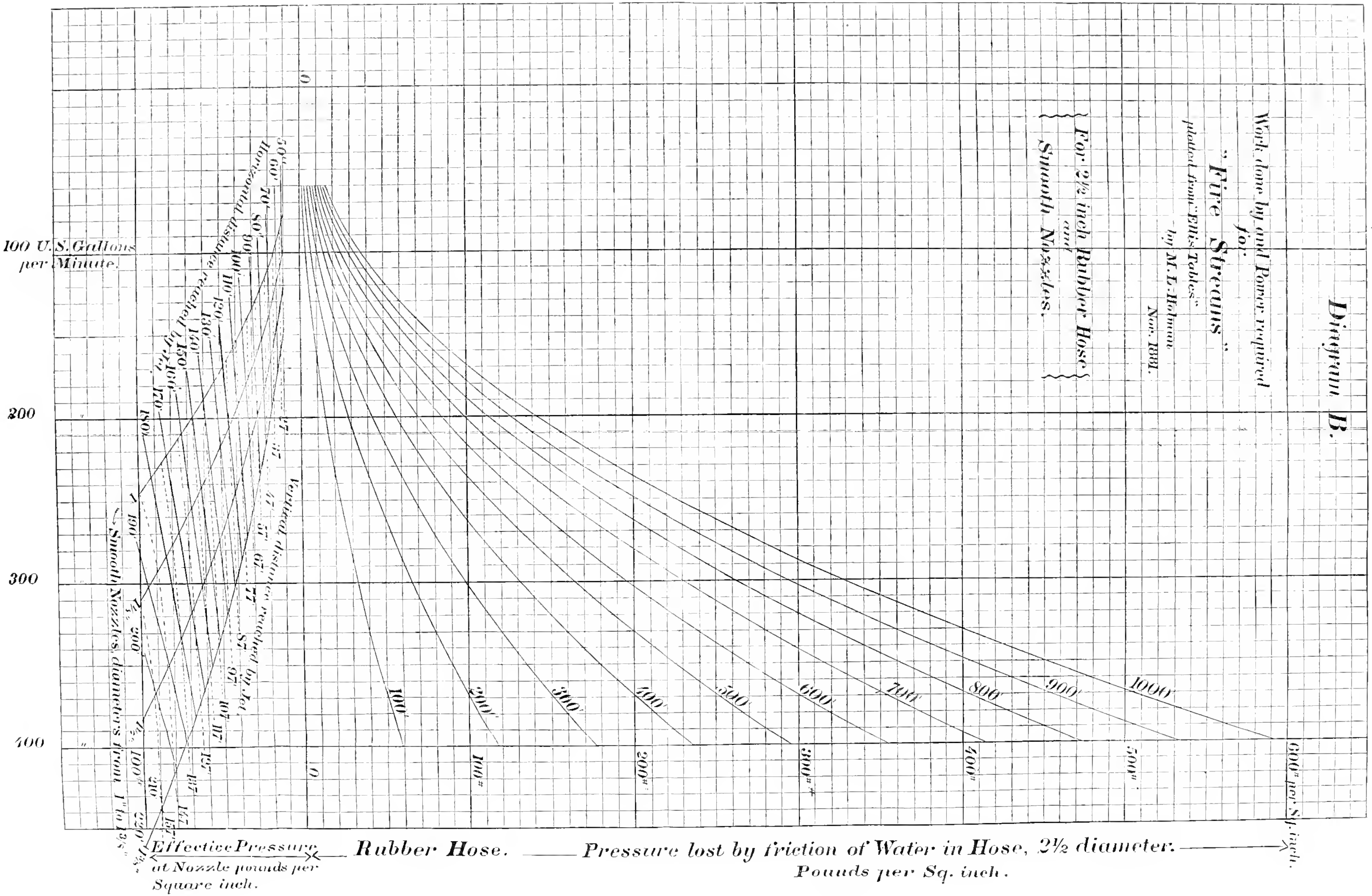


Diagram B.
Work done by and Power required for "Fire Streams" plotted from "Ellis Tables" by M. L. Holman Nov. 1881.
For 2½ inch Rubber Hose and Smooth Nozzles.
100 U.S. Gallons per Minute.
200
300
400
Horizontal distance reached by Jet.
Vertical distance reached by Jet.
Smooth Nozzles, diameters from 1" to 1⅜".
100'
200'
300'
400'
500'
600'
700'
800'
900'
1000'
0
100#
200#
300#
400#
500#
600# per Sq. inch.
Effective Pressure at Nozzle pounds per Square inch.
Rubber Hose.
Pressure lost by friction of Water in Hose, 2½ diameter. Pounds per Sq. inch.

supposition that a pressure of 200 pounds per square inch was maintained in the air chambers. Engine No. 15 was using two short lines of hose, and the quantity estimated is in all probability fully up to the quantity the engine was throwing. The above amounts are below the capacity claimed for the engines, but are somewhat in excess of the amounts as found from the diagram corrected for differences in level between engines and nozzles.

For the loss of head due to friction of water in the distribution pipes the following formulæ are selected for illustration :

Let h = loss of head by friction in meters.
l = length of pipe in meters.
d = diameter of pipe in meters.
v = mean velocity of flow in meters per second.
g = 9.81 metres.

$$h = \left(0.01439 + \frac{0.0094711}{\sqrt{v}}\right)\frac{l}{d}\,\frac{v^2}{2g} \quad \text{[Weisbach].}$$

$$h = \left(0.0273346 + \frac{0.0013597}{v}\right)\frac{l}{d}\,\frac{v^2}{2g} \quad \text{[Prony].}$$

$$h = \left(0.01989 + \frac{0.0005078}{d}\right)\frac{l}{d}\,\frac{v^2}{2g} \quad \text{[D'Arcy].}$$

The following by Kirkwood is also given for turberculated pipes :
h = loss of head in feet by friction.
l = length of pipe in feet.
v = mean velocity of flow in feet per second.
d = diameter of pipe in feet.

$$h = \frac{v^2\,l}{1600d}$$

Plot A is a graphical illustration of the loss of head for 100 feet of 6-inch pipe according to the above formula.

Distances on the line AB are laid off from A toward B to represent velocities from 2 feet to 10 feet per second.

Ordinates from AB upward represent the loss of head in feet per 100 feet of 6-inch pipe. The curves are marked with the names of the authorities giving the formulæ by which the curves are calculated.

The pipes in question are not in as bad condition as the tuberculated pipes from which Mr. Kirkwood derived his formula. The formula used for calculating loss of head in the present case is as follows :

h = loss of head in feet by friction.
l = length of 6-inch pipe in feet.
v = mean velocity of flow in feet per second.
$h = 0.001\,v^2\,l$.

The curve corresponding to this formula is also shown on plot B.

The total amount estimated for the supply to the 10 engines under consideration is a little less than 3,400 U. S. gallons per minute, or an amount equal to that supplied by a 6-inch pipe, with a mean velocity of about 38.3 feet per second.

The supply is assumed as coming through the 6-inch pipe at Seventh

and Walnut streets, Seventh and Market streets, Tenth street and Clark avenue, Eleventh street and Clark avenue, and through the 6-inch pipe in alley west of Eleventh street, from Chestnut street.

The supply from 4-inch pipe between Seventh and Eighth streets, connecting the 15-inch on Clark avenue, to 6-inch on Walnut street; the supply around engine No. 14 by 4-inch pipe in alley west of Tenth street, and the supply from the 6-inch on Market street from alley west has been disregarded. The only result of this is to reduce the pressure as figured at the engines. The reduction is slight, and is nowise detrimental to the performance of the engines, but rather throws the burden of proof as to an efficient supply on the distribution system.

The total supply gives a mean velocity of supply of 7.65 feet per second for each of the five 6-inch feeders.

To find the probable velocities, we first plot the curve whose equation is $v^2 = 2gh$, as shown on diagram C. Velocities from 4 to 13 feet per second are plotted as abcissas, and the corresponding values of h as ordinates. The curve

$$h = .5 \frac{v^2}{2g}$$

is next plotted with values of v as abcissas; but the ordinates are measured from the curve $v^2 = 2gh$. The curve

$$h = .5 \frac{v^2}{2g}$$

is again plotted, using the last curve as starting point for ordinates.

This gives us the three lower curves on diagram C.

The ordinates to first curve give the head due to the velocity or loss of head necessary to generate the velocity.

The ordinates to the second curve, or curve BD, give the loss of head due to velocity and the connection to large pipe when made with a branch and valve.

The ordinates to curve AC represent loss of head due to velocity and connection when made with a saddle and valve.

The equation adopted for use in this investigation is, as before stated,

$$h = 0.001\ v^2 l, \text{ for 6-inch pipes.}$$

For convenience in plotting the curves used to adjust the velocities in the different pipes the left hand part of diagram C is constructed.

Distances, from 1 to 1,000 feet, are laid out on the axis of abcissas to a scale of 1 inch = 100 feet.

Radiating lines from the origin are drawn, so that the ordinates to any line represent the loss of head [by formula] due to the velocity marked on that line for the length of 6-inch pipe, as shown by the corresponding abcissa.

By means of the diagram last described we plot the curve representing the loss of head due to friction in the pipe on Walnut street, from Seventh street to Tenth street. The ordinates to this curve are measured from the curve AD, as the connection at Seventh street and Walnut street is made with a branch and valve. The curve thus obtained is marked EF, and the ordinates represent the loss of head in the main pipe in Walnut street from Seventh street to Tenth street for velocities from 5 feet to 8 feet per second.

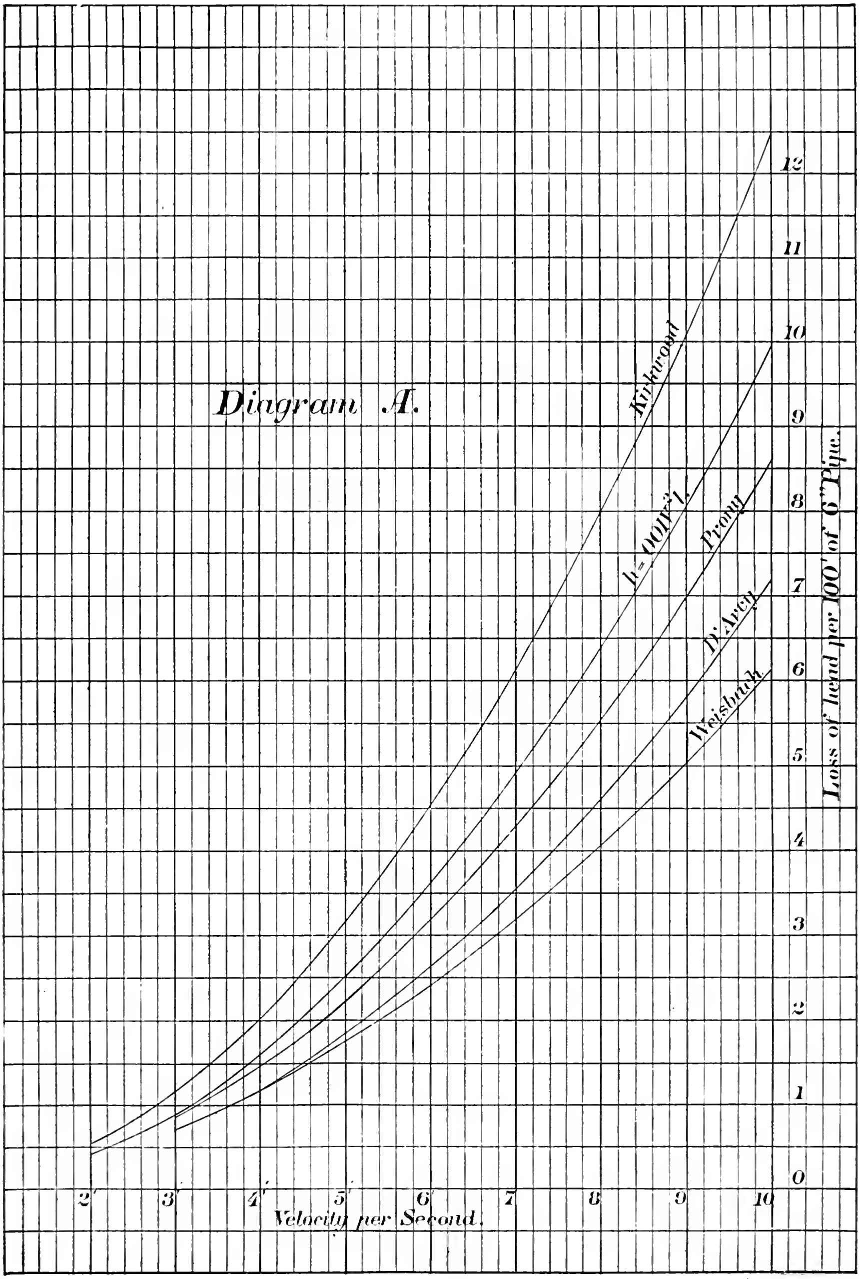
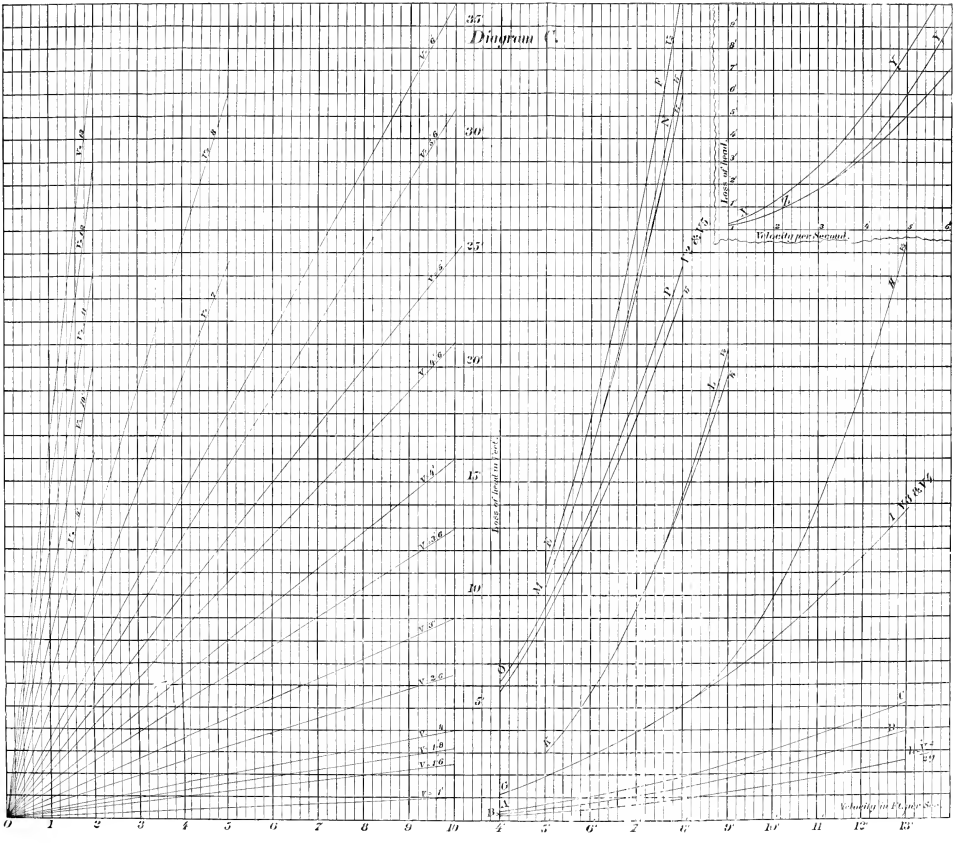
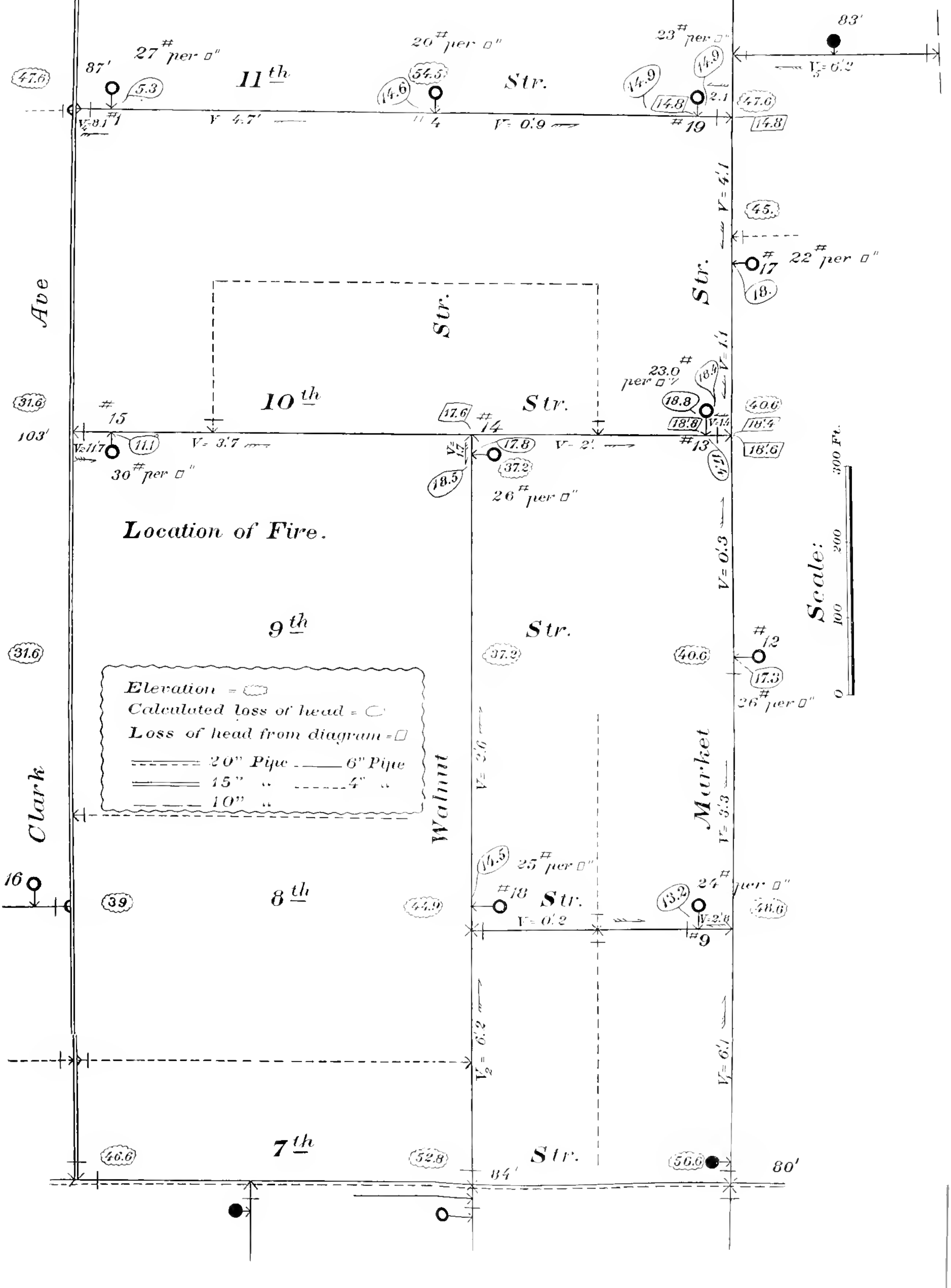


Diagram A.
Kirkwood
h = .0011V²l.
Prony
D'Arcy
Weisbach
12
11
10
9
8
7
6
5
4
3
2
1
0
Loss of head per 100' of 6" Pipe.
2'
3'
4'
5'
6'
7
8
9
10
Velocity per Second.



WATER DISTRIBUTION AND PERFORMANCE OF ENGINES. HOLMAN.

Diagram D.



Clark Ave
11th Str.
10th Str.
9th Str.
8th Str.
7th Str.
Walnut
Market Str.
Str.
Location of Fire.
Elevation = ◯
Calculated loss of head = ◯
Loss of head from diagram = □
20" Pipe
15" "
10" "
6" Pipe
4" "
Scale:
0 100 200 300 Ft.
27# per □"
20# per □"
23# per □"
22# per □"
23.0# per □"
30# per □"
26# per □"
25# per □"
24# per □"
26# per □"

The loss of head in main pipe in Tenth street, from Clark avenue to Walnut Street, is next plotted as ordinates from the curve *AC*, as the connection at Tenth streeet and Clark avenue is made by a saddle and valve. This gives the curve *GH*.

The loss of head in main pipe from Tenth and Walnut street to Tenth and Market street is plotted in small diagram, in upper right hand corner of Diagram *C*, and gives the curve *XY*.

The loss of head in main pipe on Eleventh Street, from Clark avenue to Market street, is plotted as shown by curve *KL*; the ordinates are measured from curve *AC*, the connection being made by a saddle and valve.

The curve *MN* represents the loss of head in main pipe from Seventh street and Market street to Tenth street and Market street, and plotted from curve *BD*, as the connection is similar to that at Seventh and Walnut street.

The curve *OP* represents the loss of head in 6-inch pipe in alley from Chestnut street to Market street west of Eleventh street.

The loss of head in pipe in Market street from Eleventh street is shown in small diagram by curve *ZY*.

For all of the above curves the loss of head is plotted as an ordinate from the abcissa representing the velocity.

The approximate velocities and losses of head can now be easily found, and the results are shown on plot D. The direction of flow in each pipe is indicated by a small arrow, and the velocity in feet per second is given. The head on the main pipes was found by pressure gauges a few days after the fire, the pressures being taken at the same time of day that the fire occurred. An allowance of 10 feet head has been subtracted from the head, as given by the gauges.

The losses of head in feet, as given by diagrams, are indicated at the points on diagram D, where the loss occurs, by ▭ inclosing the figures.

The calculated losses of head in feet are shown by ○ inclosing the figures.

The resulting pressures at the plugs are put down in pounds per square inch.

The diagrams furnish a very good approximation to the velocities and losses of head, and with some little care give results sufficiently accurate for practical purposes.

The time and labor saved is also quite an item, as any one can testify who will assume a complicated case and solve it by the two methods.

PROCEEDINGS.

JUNE 2, 1881:—The 207th meeting called to order by the President. Minutes of last meeting read and approved.

Committees reported progress.

Mr. Wm. Cordes was balloted for and duly elected a member.

Accounts of experiments upon a Gas Engine Trial were given by Mr. Sobolewski and C. A. Smith, and a general discussion took place thereon.

A letter from the American Society Civil Engineers was read, inviting the club to be present at the Montreal meeting on June 15.

The Secretary was instructed to answer.

On motion adjourned.

OCTOBER 1, 1881:—The 208th meeting called to order by the President. Minutes of last meeting read and approved.

Report of action made of Board of Managers by C. A. Smith.

On motion the Treasurer was authorized to forward the fee of 50 cents per member to Mr. H. G. Prout, No. 12 Barclay street, New York, the Secretary of the Board, and to pay to the order of Mr. Prout the further sum of $1.50 per capita of mailing list and four extra copies to the libraries (M. L. A., P. S., and W. U.) W. W.

A discussion on pump packings took place in which all members present participated. On motion adjourned.

NOVEMBER 2, 1881:—The 209th meeting called to order by the President. Minutes of last meeting read and approved.

Report concerning rates of advertising in JOURNAL of ASSOCIATION OF ENGINEERING SOCIETIES received.

Mr. C. T. Aubin was proposed as a member by Messrs. Whitman and C. A. Smith.

Mr. L. E. Cooley read a paper on the "Construction and Results of Screen Dykes on the Missouri River," which was discussed and questioned upon by Messrs. McMath, Whitman, Smith and Moore. On motion Mr. Cooley was voted thanks for his description.

A committee to be appointed by the President for the arrangements for the annual meeting was authorized. On motion adjourned.

NOVEMBER 14, 1881 :—210th meeting called to order by President. Minutes of last meeting read and approved. Messrs. McMath, Blaisdell and Belcher were appointed a committee for arrangements for the annual meeting.

A paper on the "Distribution of Water at the Collier Fire" was read by Mr. M. L. Holman, and a very interesting discussion took place thereon.

A vote of thanks was given Mr. Holman for his able and instructive paper. Mr. Wise exhibited some specimens taken from the bottom of the Twelfth street sewer, between Gratiot and Poplar streets, showing erosion of bricks and agglomerations of foreign matter. On motion adjourned.

DECEMBER 13, 1881 :—211th meeting held at the St. Louis Club House and called to order by President. Minutes of last meeting read and approved.

Mr. C. T. Aubin was duly elected a member of the Club.

The annual report of the Secretary was received and filed.

The Secretary and Mr. F. H. Pond were appointed a committee to solicit advertisements for the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

Mr. McMath reported nominations of officers for the following year :

President, C. Shaler Smith ; Vice-President, Wm. Wise ; Treasurer, E. D. Meier ; Secretary, C. A. Smith ; member of Board of Managers of Association of Engineering Societies, C. A. Smith.

These nominees were then duly elected.

Committee on quarters reported and was continued.

Mr. Wise was escorted to the chair.

A vote of thanks was carried to the retiring President for his valuable services to the Club during the year.

WESTERN SOCIETY OF ENGINEERS.

ORGANIZED 1869.

TRANSACTIONS.

TESTS OF COMPLETED COMPRESSION MEMBERS, WITH REFLECTIONS UPON THEIR DETAILS.

By E. J. Ward, Member of the Society.

[Read December 20, 1881.]

The tests, of which the accompanying is a report, were made at the works of the Keystone Bridge Company, Pittsburgh, in accordance with the specifications of the Chicago & Alton Railroad Company. Not to my knowledge have full-sized posts, with the detail hereafter mentioned, been tested to rupture before; and to some it may be interesting to know its effect, for it is of almost daily occurrence.

When posts are to be constructed of laced channel bars, it has become a frequent custom to cut away the flanges of the channels to permit of the close packing of the chord bars and braces, and, in some cases, to give space for the top chord. This is done for the purpose of obtaining so small a moment upon the pin as possible. To replace the strength of the channel thus lost, as well as to give a larger pin-bearing surface, reinforce plates are riveted to the web of either channel at each end of the post. The distance above the centre of the pin-hole for which the channel flanges are cut away varies with the amount of clearance that is required by the chord bar heads and with the inclination of the tie bars, if the packing is such as to bring the latter next to the channel flange. In the tests shown, this distance varied from 5 inches to 18 inches, the latter in test No. 7 to permit the clearance of a main brace. The reinforce plates used varied in thickness from $\frac{3}{8}$ inch to $\frac{9}{16}$ inch, and they were extended along the webs of the channels beyond the point to which the flanges had been cut away.

These plates, it was believed, would amply replace the strength lost by the cutting of the flanges. This, however, was found to be a mistake, not only involving loss of strength, but complicating the character of the strut.

All, except No. 6, failed below the stress that posts of their weight and description are calculated to bear. All, except No. 5, failed in such a manner as to plainly point to the extreme weakness existing between the

centres of the pin-holes and the full channel flanges, showing that the reinforce plates used failed to give the required strength. Test No. 3, having a ratio of length to least diameter of 15.75, failed at the same stress per square inch as test No. 1, which had a ratio of 18. The calculated difference in their ultimate strengths is, however, 1,240 pounds per square inch. Test No. 6, with a ratio of nearly 39 diameters, failed only 1,100 pounds per square inch under No. 7, with a ratio of 31, and only 4,000 pounds per square inch under No. 3, with a ratio of 15.75. The calculated difference in the ultimate strengths of Nos. 6 and 7 is 6,200 pounds per square inch, and between Nos. 6 and 3 it is 12,000 pounds per square inch. Two, Nos. 1 and 6, failed before the elastic limits of their bodies had been reached. The maximum deflection of all, except No. 2, was in the direction of the greater diameter, which is contrary to the assumption made in calculating the strength of such columns. The diameter of No. 2, in the direction of maximum deflection, was only 0.08 inch less than its greater diameter: and, evidently, this slight difference had very little to do with the deflecting.

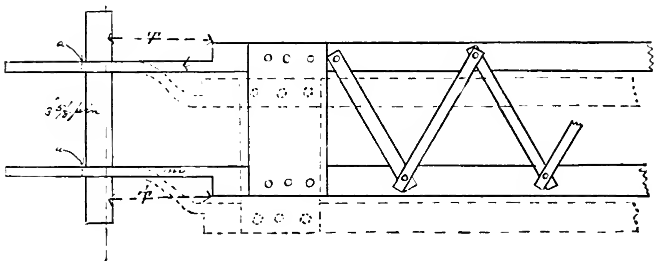
These results, both relatively and collectively, show so great a variance from the strength of such columns, when calculated from the full section and length centre to centre of pins, as, upon first thought, to almost bring one to the conclusion that but little dependence can be placed upon formulæ when such details are used.

The error lies in originally proportioning the section of the column to withstand the required total stress, on the supposition that it is to be a column with pin ends, and to have a uniform section throughout its length from centre to centre of pin-holes, and in afterward introducing a detail which changes the calculation to one of a column with flat ends, and having a very different ratio of length to least diameter, or of length to the principal radius of gyration, from that contained in the original calculation. To show this more clearly I have introduced the following sketches, taken from test No. 7 at end *H*. (See next page.)

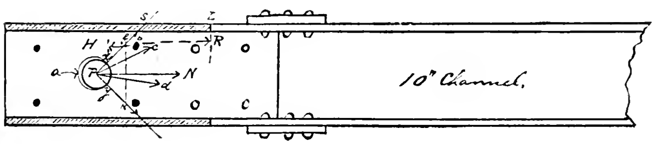
The dotted lines in sketch No. 1 represent the position of the post after giving way. With the detail in question we ought to consider only the distance $T = T' = xR$ for the length of the column—*i. e.*, the distance from the intersection of the action line of force *Ps* with the circumference of the pin-hole to the full channel flange. If this be made of sufficient strength, the full column will fail in the body, as the original calculation of its strength assumes it will. There are, also, two columns, *k* and *m*, each of which, when the distances *T* and *T'* are equal, acts almost wholly independently of the other. Each of these columns is again composed of two auxiliary columns, the pin-plate forming one and the web of the channel the other. The plate and web act more or less in unison according to the length of the former, the number of rivets and the character of the workmanship. We have considered the plate as acting independently of the web. The reason for this, I think, shows it, farther on, to be more nearly correct than it would be to assume that they acted together, on account of there having been no rivet along or near the action line *PN*. That it is right to consider the columns *k* and *m* as having flat ends is shown by the fact that failure took place by bending in the direction of the centre line of the pin, and thus no

rotation could take place on the pin. The other ends are in the line connecting the points at which the flanges are full. The latter end is, moreover, movable in direction of the planes of flexure, which will cause the column to fail under a smaller stress than if both ends were fixed. In our calculations we have considered both ends of column k as fixed.

The diameters of pins are less than those of corresponding pin-holes by from $\frac{1}{16}$ inch to $\frac{1}{50}$ inch, and, therefore, only a portion, xy, of the half circumference of the hole is brought under full compression. The initial stress is in the direction of the force PN (sketch 2), and in order to distribute this stress throughout the section of the column it is divided into the components Pb, Pc, Pd, etc., assumed as radiating from the centre of the pin.



SKETCH NO. 1.



SKETCH NO. 2.

The angle bPN is about 45° when the pin is $\frac{1}{16}$ inch smaller than the hole, therefore the material outside of this angle, as at H, gives, at most, but very little assistance in the distribution of force PN to the flanges, and hence, the section within the angle fPk must be that required by a post with flat ends and a length equal to xR, said post to be of equal strength as the full column from centre to centre of pin-holes, so constructed as to fail in the manner assumed in all preliminary calculations of posts.

In the report column "A" gives the calculated strengths of the full length columns, and also the distance in front of the pin-hole to that section where there is, within the angle of 90°, area sufficient to give a flat-end post of the length given by the detail (xR, sketch 2) the same strength as the full two-pin end columns. This area lying wholly within the web, one might, at first, suppose that the fact of the flanges having been cut away had but little to do with the ultimate strength of column k. But it must be remembered that the radius of gyration, or the least diameter, of a section of the channel between s and L is reduced to nearly that of a plate when the flange is cut away, and that the column fails by buckling and not by crushing at the pin-hole.

It is to be regretted that test No. 5 crushed at the pin-hole at the end having full channel flanges, for it might have given interesting results, one end having the flanges cut away, while the other not. In this test the crushing stress per square inch on the pin-hole was 84,100 pounds.

Test No. 4 was an end top-chord section. The angle between the lattice bars was, in all cases, 60°, as is usual in single lacing. The spreading of the channels of No. 4 might, I believe, have been, in a measure, prevented by double lacing with the customary angle of 90°, and by the use of wider connecting plates.

With the details as given the strengths of the columns are reduced about ten per cent., and the gain would be the saving of a comparatively small amount in pins and eye-bar heads.

The formula used in the report is

$$\frac{P}{s} = \frac{f}{1 + \frac{H^2}{n}},$$

in which $\frac{P}{s}$ = stress per square inch at rupture, H = ratio of length of column to diameter in direction of maximum deflection (assumed in original calculation to be the lesser diameter), f is a constant = 36,500, and n is a constant that for square-end columns = 3,750, for one square and one round-end columns = 2,250, and for both ends round = 1,750. During the testing of the posts the pins were placed in a vertical position, while the pin of the top-chord section was in a horizontal position. Cast-iron pin-blocks were used, and for the longer posts counter weights were suspended at the centre.

I here wish to thank Mr. Hemberle for his kindness in reviewing these remarks, and for giving me valuable suggestions that have added much to the discussion.

PROCEEDINGS.

December 20, 1881:—The 137th regular meeting was held at 7.30 p. m. Mr. Hemberle was called to the chair.

The minutes of the preceding meeting were read and approved.

Application to be admitted as a member was received from Robert Alexander Brown, Assistant Engineer in charge of Illinois River Improvement, Beardstown, Ill., indorsed by Messrs. Lijencrantz, Fitz Simons, and Roney.

A paper was read by Mr. E. J. Ward, illustrated by diagrams, "Tests of Compression Members and Reflections upon their Details."

After discussion of the paper, Mr. Lijencrantz introduced Mr. F. C. Wheeler, of Boston, who gave a description of a new motor designed by Colonel E. H. Augamur, of New Orleans, for use on street railways, the power being obtained by charging the boiler of the motor with steam from a stationary boiler, and the force of the steam being retained by means of a small fire.

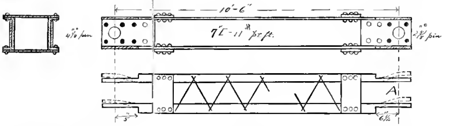
[*Adjourned.*] L. P. Morehouse, Secretary.

January 3, 1882:—The 138th regular meeting was held at 4 p. m., Vice-President Cregier in the chair.

The minutes of the preceding meeting were read and approved.

The annual report of the Secretary was read, and it was voted that the report be accepted and placed on record.

PITTSBURGH, Sept. 1 and 2, 1881



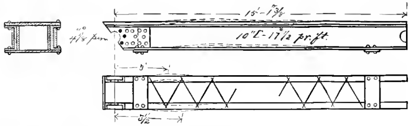
TEST NO. 1

Four pin plates [illegible]
Greatest weakness at [illegible]

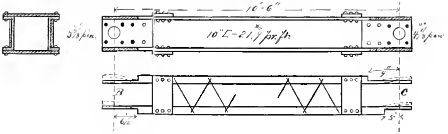
Length of column, centre to centre of pins [illegible]
Diameter in direction of max. deflection [illegible]
Least diameter [illegible]
Ratio of least diameter to length [illegible]
Weight in pounds [illegible]

Area of section, sq. in. [illegible]
Elastic limit [illegible]
Total in pounds [illegible]
Modulus of elasticity [illegible]

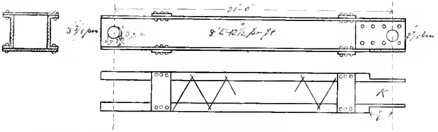
E. J. WARE



TEST NO. [illegible]

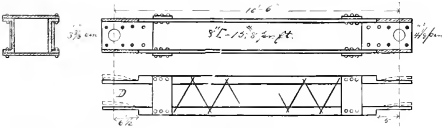


TEST NO. [illegible]

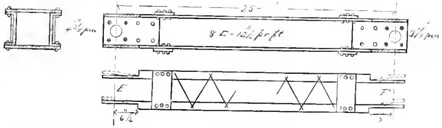


TEST NO. [illegible]

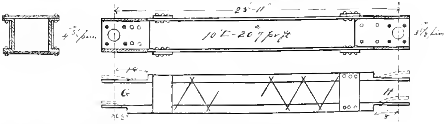
Two pin plates [illegible]
Elastic limit (not reached in body of [illegible])



TEST NO. [illegible]



TEST NO. [illegible]



TEST NO. [illegible]

Officers were elected as follows:

President, W. S. Pope; First Vice-President, D. C. Cregier; Second Vice-President, K. F. Booth; Secretary, L. P. Morehouse; Treasurer, Charles Fitz-Simons; Librarian, John W. Weston.

Mr. W. S. MacHarg was elected Trustee for three years. A paper by Samuel McElroy was read by Mr. MacHarg, "Trunk Line Field Notes."

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

REPORT OF THE SECRETARY FOR THE YEAR 1881.

The following report is submitted in accordance with Section 2 of the By-Laws, which reads as follows:

"The Secretary shall keep a record of all the transactions and fiscal affairs of the Society; shall receive all moneys and promptly deposit the same with the Treasurer; issue all notices and other documents requiring verification, and make a detailed report of his transactions at the annual meeting, or oftener if required by the Society or Trustees. The Secretary may also fill the office of Treasurer and Librarian at the pleasure of the Society."

Twenty regular meetings have been held during the year, and the transactions of these meetings have been recorded by the Secretary, and, after approval, have been entered in a book containing the records of the Society. Notices have been sent to members, previous to each meeting, calling attention to the date of such meeting, and, when practicable, stating the paper to be read. Other notices have been issued from time to time with reference to other matters. The correspondence of the Society has been attended to so far as necessary to conduct the ordinary business of the Society and to communicate with members and others upon matters pertaining to its interests.

In furtherance of the resolution adopted at the 116th meeting, two circulars have been issued, with the object of presenting the claims of the Society to engineers and others.

In addition to the above the Secretary has had occasion to confer at various times with other officers of the Society, and with different committees, upon many questions.

The following financial statement shows the amount of money collected, the amount expended, and the amount on hand at this time:

Cash in hands of Treasurer, December 21, 1880		$98.73
Cash in hands of Secretary, December 21, 1880	$8.83	
Cash received by Secretary from fees and dues	932 50	
Total amount payable to Treasurer		941.33
Total amount		$1,040.06

Orders have been made upon the Treasurer:

For stationery, stamps and notices	$113.43	
For library and periodicals	70.00	
For reporting and copying	20.00	
For rent	8.50	
For furniture	22 50	
For De Lesseps reception, to balance	59.64	
For entrance fee to Association of Engineering Societies	63.00	
On account of printing volume V., to balance	187.50	
On account of contract with *American Engineer*	225.00	
		769.57
Balance in hands of Treasurer	257.79	
Balance in hands of Secretary	12.70	
		270.49

L. P. MOREHOUSE, Secretary.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

ORGANIZED 1880.

TRANSACTIONS.

WATER WASTE AND WATER METERS.

By M. W. Kingsley, Member of the Club.

[Read March 5, 1881.]

The supplying of water for a large city, and the cost of keeping it supplied with mains of adequate size and engines of sufficient capacity and power to keep a constant pressure in the pipes, or nearly so, is a question that occupies the attention or thoughts of comparatively few of its citizens, except those most intimately connected with water or fire departments, and in a different sense by those who depend upon it for power.

Large outlays of thousands, yes, millions, are spent for these purposes, and no grumbling of any account by the people, except when they pay their taxes, never thinking for a moment that, possibly through their own individual carelessness or wastefulness, they are the prime cause of it all.

Notwithstanding these heavy expenditures, gallons are wasted to obtain a single glass of water; faucets and closets are left to waste water more or less constantly by many. They do not seem to realize that if 5 gallons are wasted to the one needed, the pumping power and mains must be increased in a corresponding ratio.

The American system of supplying consumers practically unrestricted at a given price per year has caused the people in the different cities to be very extravagant and wasteful, much more so than in European cities.

The following figures of the daily gallons of water per inhabitant used by American and foreign cities in 1877 show a marked difference:

Foreign Cities.	Gals.	American Cities.	Gals.
Dublin	60	Providence	25
Glasgow	52	Fall River	26
Paris	38	Boston Cochituate Works	74
Edinburg	35	Brooklyn	63
London	33	Cincinnati	57
Liverpool	30	Philadelphia	58
Manchester	21	St. Louis	56
Sheffield, Eng.	20	Cleveland	56
		Detroit	105
	289	Chicago	119
Average	36.1		639
		Average	63.9

36.1 gallons against 63.9, making a difference of 27.8 gallons per inhabi-

tant per day more in American than in foreign cities: this is ample for all legitimate uses in any city per inhabitant.

One of the most serious wastes is caused by the constant small streams running in closets and other fixtures, owing to leaks or wilful negligence. The rate of consumption is sometimes doubled on a cold day or night, as compared with a moderate one.

People are not careful enough about where their plumbing is located when building; the house is planned and the plumber is left to put the pipe in as best he can; if, in a block, it has to be run up in a cold hall, or along an outside wall, where the water must be run to keep from freezing: far better give your plumbing into the hands of a good reliable plumber to plan together with the architect, or else spend a little more time yourself and use your own common sense.

The following experiments were made in the basement of the water-works office, in this city, to find the time it took to discharge 100 cubic feet, or 748 gallons, through different-sized circular orifices, while water was being used elsewhere in the building:

$\frac{1}{16}$-inch orifice,	100 c. ft.,	or 748 gals.,	20 hrs.	20 ms.
$\frac{1}{8}$ "	"	"	5 "	33 "
$\frac{3}{16}$ "	"	"	2 "	02 "
$\frac{1}{4}$ "	"	"	1 "	39 "
$\frac{5}{16}$ "	"	"	1 "	22 "
$\frac{3}{8}$ "	"	"	1 "	15 "
$\frac{7}{16}$ "	"	"	1 "	10 "
$\frac{1}{2}$ "	"	"		55 "
$\frac{3}{4}$ "	"	"		37 "

The smallest orifice, $\frac{1}{16}$, will discharge about 322,000 gallons in a year if left to run constantly, and a $\frac{1}{4}$-inch orifice 39,708,000 gallons, equal to $3\frac{7}{10}$ days' pumping, as shown by the records of 1880.

When it is seen how much water can pass through a small opening, and a moment's thought is given, to think of the places that are in all probability wasting, is it any wonder that you do not get water in the fourth story of your blocks, or that the pressure is weaker at times?

Out of 7,762 inspections made of buildings in New York City in 1880, 1,592 leaks in fixtures and 261 cases of willful waste were discovered. About one-fourth of all the inspections were found out of order. In all probability a similar inspection would reveal the same state of affairs here.

The aggregate area of the taps and connections with the Croton pipes of New York is 170 square feet, and the aggregate number of faucets or orifices for drawing water is 5 to each tap.

The area of Croton Aqueduct is 53 square feet: the area of openings being $3\frac{2}{10}$ times greater than the aqueduct.

In Cleveland the areas of all the taps and connections in use are 28.5 square feet, and the areas of the mains are 13.4 square feet, showing that the connection or tap areas exceed the supplying area $2\frac{1}{10}$ times. If one-quarter of all the services should chance to draw water at once, it would seriously affect the pressure, and if about one-half the number, allowing that they were drawing the full capacity of the pipes, it would be equal to the supplying areas.

The following table gives some interesting and reliable data taken from different reports :

City.	Year.	Population.	Daily average consumption in gallons.	Daily average consumption in gallons per inhabitant.	Number of services.	Miles of pipe.	No. of meters.
Providence	1877	100,000	2,500,800	25	7,420	144	3,203
Fall River	"	45,000	1,173,600	26	2,060	48.4	881
Boston Cochituate Works	"	280,000	20,673,500	74	46,470	300	1,079
Brooklyn	"	485,000	30,343,900	63	54,879	338.3	930
New York	"	... ...	... ...	...	... ...	440 0	400
Cincinnati	"	280,000	15,945,210	57	20.000	......	304
Philadelphia	"	817,500	48.984,000	58	....	710	16
St. Louis	"	400,000	22,349,443	56	16,800	185	350
Cleveland	"	136,000	7,726,920	56	7,760	108	248
Detroit	"	110,200	11,543,120	105	18,754	194	9
Chicago	"	440,000	52,183,900	119	64,898	425	1,623
Cleveland	1880	156,000	10.207.000	65	10.013	125.6	402
Providence	1879	... .	3,110,279	...	9,139	152	4,036
New York	1880	....	....	...	....	503	4,000

Providence, in 1879, with 9.139 service pipes, has 4,036 meters, while Fall River has about 52 per cent. of all her connections metered.

New York has increased the number of meters in the last 3 years 3,600, making a total of 4.000.

From the foregoing table it will be seen that the waste of water is greatest where the least restrictions are placed.

Boston, in 1848, estimated 30 gallons per day per inhabitant ample supply. At the end of 10 years, allowing for an increased population of 175,000, it was thought 5,250,000 gallons would be required daily: and at the end of another decade, 7,500,000 gallons ; the result ! in 2 years the anticipated demand was exceeded, and in 10 years 5.000.000 gallons more were used than was expected in 20 years.

Here is one of the most economical cities in the United States forced to the conclusion "that the only remedy found was the general adoption of meters throughout the city, and an entire change in the assessment and collection of rents." (Report of 1861.)

Eight years later the authorities report : "The number of meters applied is 1,021, being an increase of 126 over the previous year, and it gives us pleasure to state that we have had fewer complaints from the meter system this year than any year since their application." (Report of 1869.)

HOW THE METER SYSTEM WORKS ELSEWHERE.

"There is no way to effectually check the waste, except by a general use of the meter, which will at once render the distribution of water just and equitable. No system can be considered permanent and reliable not based upon measuring the water to each customer." (Brooklyn, 1861.)

"The Board now have in use 131 meters, and are entirely satisfied with their working ; they have to a great extent checked the extravagant waste of water." (Baltimore, 1869.)

"Wherever meters have been introduced they have given satisfaction, not only to the supplier, but to the consumer. Without them the proper

rent can only be approximated, and it is possible that the consumer may frequently be overtaxed, or the reverse.

"By the meter system he pays only for what he actually consumes." (Philadelphia, 1869.)

"One remedy for waste is to charge all using over a stipulated amount for the excess, to be determined by meters." (Albany, 1869.)

"The use of meters is the only possible equitable mode of making assessments." (Worcester, Mass., 1871.)

"The prejudice which formerly existed against the use of meters is gradually giving place to a feeling of confidence in this method of determining the water assessment." (Chicago, 1871.)

"That for all legitimate purposes whatever in a city like ours, it should require a hogshead and a quarter per day for each man, woman and child is not possible, and is simply evidence of enormous waste; everywhere the conviction is gaining strength that nothing but meters can do this within available means." (Chicago, 1878.)

"The account of nine out of every ten customers changing from the assessment plan to meter rates is reduced; on the other hand not one in the ten meter customers would consent to go back to the assessment plan.

"One of two things would certainly follow the universal application of meters, either the quantity of water required for the daily supply of the city would be reduced one-half, or the revenue of the works be doubled. In the former case expenses would be largely reduced, and in the latter the ability of the works to obtain the larger supply and extend the distribution would be vastly increased." (Columbus, 1879.)

In New York Report of 1880 I find that from the continued pipe extension and the constant decrease in water pressure it has made the use of the meter necessary on all business establishments; they have set 797 meters in the past year. The registers show that in some of the large hotels and institutions where many servants are employed the daily consumption per inmate reached 100, and in some instances 200 gallons.

They estimate that when the system which they have adopted of metering all business establishments using large quantities of water is carried out, that they will make a daily saving of 10,000,000 gallons (about equal to Cleveland's daily average supply for 1880), and that if carried still farther, to the private dwellings, they would be able to decrease the amount at least 40 per cent.

These authorities, and many more which I might quote, speak with a full knowledge of the subject that would be hard to controvert, being the own words of superintendents and purveyors of water departments who have given the subject years of careful study.

In one large hotel in New York the meter showed, when first set, 115,000 gallons daily; this was reduced in a short time to 45,000 per day. In another, 80,000 was being used, which was decreased to 24,000 gallons per day.

I might mention numerous instances of detecting leaks in our own city, which would not have been found but for the meter, where water was making its way into the sewers or in sandy soil: and in other cases where careless help was wasting it unknown to their employers, or by the neg-

ligence of janitors in some of our large blocks, and especially in blocks rented out where the owner pays the water rent, the tenants little caring whether the owner has to pay thirty or three hundred dollars.

Many water takers have the erroneous idea that it is more expensive with a meter than without, which will be forcibly illustrated by the assessment and meter rates of two prominent blocks in our city:

By assessment............ ....$148.13	By meter................$78 90	= $69.23	saved.
By " 90.00	By " 68.64	= 21.36	"

In many instances the first bill is large, equal to or exceeding assessment rates, but afterward, owing to care and attention, the amount is often reduced 50 per cent. at next collection. There is no other way of collecting so equitable and satisfactory to both consumer and supplier, especially in such cases as livery stables, which are full one season of the year and only partially so at another; also blocks, which are constantly changing their tenants, being full to-day and vacant next week, and all places demanding an intermittent supply; also buildings fitted with hopper closets not self-closing.

In the report of 1879, Boston gave an account of five different trials made with non-closing hopper closets, and substituted self-closing pan closets instead.

Case No. 1, of 5 closets, after a trial of 1 year each by meter, showed a difference in favor of the pan closet of 703,919 gallons.

Case No. 2, of 3 closets, same time, showed a difference of 1,235,611 gallons.

Case No. 3, of 1 closet, same time, showed a difference of 454,208 gallons.

Case No. 4, of 3 closets, same time, showed a difference of 380,406 gallons.

Case No. 5, of 1 closet, same time, showed a difference of 475,595 gallons.

The total gallons saved by the substitution was 3,249,739, or a daily saving of 685 gallons per closet.

Closets that will not close themselves similar to the pan closet are often inadvertently, negligently, or wilfully left unclosed.

As a matter of comparison, out of about 5,000 water-closets in the city, say that one in 20 or 250, are not closed, or if a pan closet, that it is propped up, and is wasting at the same rate as the Boston closets, namely, 685 gallons per day, the enormous quantity of 62,506,000 gallons in a year, would have been wasted; for it is all waste, as the 685 gallons per day was an actual saving between the two classes of closets after having used all that was necessary with the pan closet, and if it were paid for at our meter rates, which are the lowest of any in the country, would amount to $31,413.

The first English patent on a water meter was in 1825, and the first American patent in 1848; this was for measuring the flow of liquids from a cask or tank. From 1848 to 1877 there had been granted 300 patents on water meters. The meter system, like everything else, has its opponents. General Fitz John Porter, late Commissioner of Public Works of New York, says: "It is a disputed point whether it is desirable in a large city, with its vast system of sewerage, to check the free use of water," and

says "it is claimed that what is wasted in New York is absolutely necessary to cleanse the closets and vaults.

"All water goes into the sewers, and the more we can afford to let run through the sewers and private drains the more effective we render our sewerage system."

He, with many others, claims that the introduction of the meter would cause people to economize, and in many localities in cities it would induce such a niggardly use of water as to endanger the *public health ;* that less water would be used, and that the sewage, from want of sufficient flush water, would remain in the drains, where it would decompose and generate sewer gas.

On the other hand, it is claimed by the friends of the meter system that the sewers derive no practicable benefit from the thousands of driblets, which do not seem to clear a single foot of drain ; that water-closets that require a constantly running stream of water to make them tolerable, and pipes that render the soil damp by leaking, so far from promoting the *public health*, are, on the contrary, among the enemies against which it has to contend : that a few gallons of water suddenly discharged into a drain is far more effective than constant flowing driblets.

Upon this last point Baldwin Latham, the distinguished sanitary engineer, says:

"It is found by experience that a small volume of water running quickly and at once through a water-closet or drain is more effective than ten times the same quantity supplied in small driblets."

METERING OF PRIVATE HOUSES.

No large city can afford to be niggardly or small in its supply of water; especially to the private dwellings; but it has a right to expect its consumers to deal justly and not waste.

In case of metering private dwellings, and still not have the occupants feel that they had to count the drops for fear of wasting, probably the best plan would be to allow what has been found to be ample from accurate measurements to supply all demands of a family, and charge a given amount per capita or room; and any excess over that, as shown by the meter, which would represent luxury or waste, to be charged for at a given rate per cubic foot or gallon.

By such a system the immense waste of water would be prevented, yet sufficient would be used to preserve the public health, and the water would be more evenly distributed.

When illuminating gas was first introduced it was sought to estimate the consumption, but it was soon found that an accurate system of measurement was the only thing between the companies and failure. From the records of Providence, Fall River, Worcester and other Eastern cities, where householders have the option of purchasing and applying meters, fully 60 per cent. prefer buying water that way.

It seems to be an established fact that cities like Cleveland, especially manufacturing cities, and growing as rapidly, have to double their capacity about every eight or ten years. If it were not for our 402 meters we now have, which cost the city about $19,000, we should to-day have invested in pumping machinery and mains over $200,000 more than

there is at present, and the works would be no more effective, while in all probability we would be pumping 12,000,000 gallons daily instead of 10,000,000.

We are frequently asked "Are the meters reliable? Do they measure correctly, and do they deliver as much water as they register?"

Again, it is asserted that a perfect meter is not yet made. Strictly speaking this may be true, for it is a difficult matter to construct a meter that will allow no water to pass without registry.

But this gives the consumer the benefit of the loss. When meters are perfected as they now are to register water discharged through an orifice $\frac{3}{100}$ of an inch in diameter, and in some instances $\frac{1}{100}$ of an inch in diameter, water departments need not hesitate about putting them in on the grounds of imperfection.

We are usually satisfied if a meter works on a $\frac{1}{16}$ inch orifice, and have large 3-inch meters that will do that.

In cases where persons doubt the registry of the meter, we prefer to test its accuracy in their presence at the Water Office basement, where such facilities are provided.

In several instances consumers have found fault, and expressed a desire to see an actual test, and in every test the meter fell short of the actual quantity delivered; and they have gone away satisfied that they must look in another quarter to account for the large amount passed through it, and the next six months proved by a large decrease that they had located it.

The quantity of water pumped during 1880 was 3,725,683,021 gallons, being an increase over 1879 of 270,411,040 gallons, and a daily increase of 712,963 gallons; the rate of increase for the year being $7\frac{82}{100}$ per cent.; the annual average increase one year over another for the last 23 years has been $14\frac{38}{100}$ per cent.

If Cleveland was metered as thoroughly as some Eastern cities are, the daily average gallons pumped would not exceed 5,000,000, while it now reaches 10,000,000.

The impression of many is that water should be "free as air." This no one will deny, if they will only go to the fountain head, Lake Erie, and seek it at its level. The prices charged are for transportation, distribution and maintenance more than for the fluid itself.

Cities or towns having works built with a capacity sufficient for supplying it with its natural increase for 10 or 15 years are apt to be so lenient and careless that their regulations, as regards waste, are in a short time practically a dead letter; and really the cost of pumping a few thousand gallons more or less amounts to mere nothing, as their expenses consist of interest on construction and running expenses. But here comes the evil. People have acquired such wasteful habits from this leniency that from two to three times more water is pumped than is necessary, and in the course of 6 or 8 years additional machinery and larger mains must be provided to meet the exorbitant demand.

[After the reading of Mr. Kingsley's paper, and, upon his invitation, the members adjourned to the basement of the water-works office, to inspect the different water meters in use, and the manner of testing the same by the department.

Duplicates of the meters shown were taken apart for inspection by Mr. Kingsley, who is Assistant Water-Works Engineer.

In testing meters a large tank is used, holding 100 cubic feet of water and provided with a glass tube, graduated to cubic feet and fractions.

To this tank a $\frac{3}{4}$-inch Ball & Fitts', a 1-inch Crown and a $1\frac{1}{2}$-inch Worthington meter were attached by separate pipe connections, the reading of the meters taken, water turned on simultaneously and allowed to flow uninterruptedly and at full head for $13\frac{1}{4}$ minutes, until the tank registered 100 cubic feet, when water was turned off and the reading of the meters again taken: the first having registed 21, the second 32 and the third 47 cubic feet, giving a total of 100 cubic feet, as shown by the tank.

After emptying the tank, a second test was made by running into it 25 cubic feet through the 1-inch Crown meter alone, the water being turned off and on 25 times during the operation, as might occur in actual use, and the result noted. First reading of meter, 67; second, 92; difference, 25 cubic feet, the same as shown by the tank.

During these tests, and to show the accuracy with which very small as well as large streams can be measured, and also the amount of waste which a very minute leak may occasion, water was turned onto a $\frac{5}{8}$-inch Worthington meter, and passed out through an orifice about the size of a common pin, or $\frac{3}{100}$ of an inch diameter, into a tank containing 1 cubic foot—the tank standing on a platform scale, balanced. This stream was continued about 40 minutes, when the meter registered $\frac{4}{10}$ cubic feet, the water in the tank weighing 25 pounds, or just $\frac{4}{10}$ of a cubic foot, taken at $62\frac{1}{2}$ pounds.

Owing to the lateness of the hour, the balance of the tank was filled with the full $\frac{5}{8}$-inch stream from the meter, or until the scale turned at $62\frac{1}{2}$ pounds—the meter reading 1 cubic foot—when the experiments ended.

The members then adjourned, with a vote of thanks to Mr. Kingsley for his demonstration of the fact that it is possible to measure the water supply of cities, whether in large or small quantities, with an accuracy sufficient for all practical purposes.—M. E. R.]

THE RISE AND FALL OF A RAILROAD COMPANY, 1837–42.

By C. P. Leland, Member of the Club.

[Read May 15, 1880.]

The railway system of the world, gigantic as it is, is but 50 years old. When George Stephenson successfully ran his little locomotive, the Rocket (crude as it was, it contained every essential principle of the great locomotives of the present day) over the Manchester & Liverpool Railway, September 15, 1830, it was instantly recognized as the motive power of the future.

For two or three years prior to this great event the ingenuity of our inventors in this country was actively engaged in producing a locomotive. In the summer of 1830 a queer-looking machine, resembling a huge porter

bottle, hung in the midst of four wheels, named Best Friend, was built at the West Point Foundry for the South Carolina Railroad—our first steam railroad—on which it was placed in November, 1830. It made several trial trips, running at the rate of 16 to 21 miles an hour with four or five small passenger cars, and 30 to 35 miles an hour alone. The fate of this pioneer locomotive of America is graphically depicted by Mr. Charles Francis Adams, Jr., in his valuable work, "Railroads, their Origin and Problems."

He says: "It was not long, however, before the Best Friend came to serious grief. Naturally, and even necessarily, inasmuch as it was a South Carolina institution, it was provided with a negro fireman. It so happened that this functionary, while in the discharge of his duties, was much annoyed by the escape of steam from the safety valve, and, not having made himself complete master of the principles underlying the use of steam as a source of power, he took advantage of a temporary absence of the engineer in charge to effect a radical remedy of this cause of annoyance. He not only fastened down the valve lever, but further made the thing perfectly sure by sitting on it. The consequences were hardly less disastrous to the Best Friend than to the chattel fireman. Neither were of much further practical use."

The second locomotive for this road, the West Point, was built on the principle of Stephenson's Rocket, and had arrived in Charleston in March, 1831. Four months before the mishap to the Best Friend, Europe and America started together in the work of railroad construction, and it is a singular fact that notwithstanding the accumulation of capital in the old world, and the abundance of poverty in the United States at the start, at the end of 50 years the United States has 93,671 miles of railroad in operation (equal to almost 28 roads from New York to San Francisco), and is not much behind Europe in the race.

The first decade—1830-1840—was a struggling, experimental period, during which but 2,818 miles of railroad were built in the United States. The first railway project in which the few people then in Northern Ohio (the census of 1830 gave Cleveland a population of 1,075) were specially interested was that of Col. De Witt Clinton, of New York, a civil engineer of prominence, but not *the* De Witt Clinton, who built the Erie Canal. He promulgated in 1829 a plan for the Great Western Railway, starting from New York City, thence to and up the Tioga River, intersecting the head-waters of the Genesee and Alleghany rivers; thence to Lake Erie, along the Lake Shore, crossing the Cuyahoga, Sandusky, Maumee and Wabash rivers, to its western terminus, where Rock River empties into the Mississippi, near Rock Island, Ill. The distance was 1,050 miles, and estimated cost $15,000,000. It was calculated by the projector that freight trains would traverse the line in nine days, and that the road could afford to carry freight at $1.73 per hundred pounds, about half the rate then current from St. Louis to New York via New Orleans, which route required about 50 days' time.

Soon after another and a rival project was put forth to build a railroad on piles or posts, 10 feet apart, on which were to be placed planks, 9 by 3 inches, edgewise, which supplied the tracks. No iron to be used except the bolts and nuts necessary to fasten the

planks to the piles. The projector made the following estimate for the Great Western Railroad, 1,050 miles, under this plan:

Right of way	$532,800
Rent of mills to saw planks	1,850
Getting out posts	31,400
Bolts and nuts	211,200
Leveling posts and laying rails (planks)	62,800
Setting posts and piles	31,400
Sawing	35,500
Total	$906,950

Less than a million dollars, against Col. Clinton's estimate of fifteen millions for the same road.

It is no wonder, in the universal condition of grinding poverty then existing, that this plan was very attractive, and several roads were projected and partially built on piles under this plan. Among them was the Ohio Railroad, the subject of this paper. The Ohio Railroad Company was organized at the house of I. Card, in Painesville, April 25, 1836, by a majority of the commissioners named in the act of incorporation, and a stock subscription book opened.

The line was to start from Conneaut, near the State line between Pennsylvania and Ohio, keeping close to the shore of Lake Erie and ending at Manhattan, then a paper city rival of Toledo, now a part of it. The scheme included several paper city speculations, notably Manhattan and Richmond, at the mouth of Grand River (near Painesville), named after Thomas Richmond (a brother of the late Dean Richmond), a director and one of the leading spirits in the company. Real estate speculation at this time (1836) was at fever heat, and it is hardly an exaggeration to say that the whole south shore of Lake Erie, from Buffalo to Detroit, was laid out in city lots, which were held at fabulous prices.

There was no end of real estate millionaires, when you accepted their own valuation of their property; but there was no money and no buyers, because all had lots to sell. The fearful collapse of 1837 came: the bubble burst; corner lots at fabulous prices once more became farming lands and gardens, and the millionaires of 1836 were engaged in a hard struggle to obtain food and clothing. The hard times which followed the revulsions of 1857 and 1873 were periods of booming prosperity compared with the fearful depression of 1837–1842, when the unfortunate enterprise we are considering was born and made a determined struggle for existence.

The charter was extremely liberal, bestowing upon the company banking privileges, which were utilized, as will be painfully remembered by the surviving business men of that day, for the emission of three or four hundred thousand dollars of bills. As if this were not enough, the company had the benefit of the so-called "Ohio plunder law," under which the State was forced to become a partner to the extent of fifty per cent. of the amount of capital stock subscribed and paid in by any railroad, turnpike or canal company. As the term "paid in" was construed with extreme liberality, a subscriber to stock could pay therefor with a deed of his lot or farm *at his own valuation*. After going through this form, gathering in a lot of so-called assets, the officers of the company would certify to the Auditor of State that so much stock had been subscribed and paid in, and demand State bonds to the extent of one-half the sum

so subscribed and paid in. Of course, the larger this sum the more bonds the State had to issue.

So many schemes and projects were started under the extraordinary stimulus afforded by this law, it was foreseen that the bond mill at Columbus would break down under the demand from all sections of the State, hence the law was repealed before a very large amount was issued. (See appendix.)

The Ohio Railroad Company, however, got in its work (on the subscription book) early. Seven men, who could probably have raised with difficulty $25,000, subscribed to the capital stock of this road to the extent of $600,000 without the slightest hesitation, and received $249,000 in State bonds—a dead loss to the State.

These bonds and the currency issued by the company constituted nearly, if not quite, all the means for the prosecution of the work. Serious disagreements as to the best way to raise money broke out in the Board of Directors. One plan was to purchase flour with the company's notes, ship it to New York for sale, and to use the avails as a redemption fund for the notes and for exchange, which soon was worth ten per cent. premium.

In 1836 the route east of Cleveland was surveyed and located. Then the Directors, influenced by land speculation interests, quarreled as to where to begin the work. One party insisted that the section between Fremont and the Maumee River be constructed first, while another as strenuously insisted on beginning at Cleveland, and proceeding eastward. The former plan prevailed, and the first pile was driven at Fremont, near the present L. S. & M. S. station, June 19, 1839.

About this time the Chief Engineer, Mr. Cyrus Williams, issued a most glowing report prophesying a glorious future for the Ohio Railroad. Considering the difficulties that environed him, with no statistics, and only about a thousand miles of railroad in operation in the United States, all east of the Alleghanies, his report shows great ability—and devotion to his employers.

I give extracts of some of its most striking features:

"By reference to a map of the United States, and an examination of the routes of transportation, improvements completed and projected, it will be seen that both from the east and from the west all concentrate toward and connect with the Ohio Railroad, from Maine to Virginia on the east and south, and from Lake Superior to Arkansas on the west.

"Through half the year, when navigation of the lakes is obstructed by ice, this must be the travelers' only route and the safe and regular transit by railroad must secure through the other half of the year a large portion of the travel. When we consider the delays, damages and accidents incidental to lake navigation, and the high and fluctuating prices of freight, Lake Erie will hardly be considered a rival for the transportation of passengers, merchandise and light freight." This prophecy, and indeed the whole scheme of building a railroad along the shore of Lake Erie, was ridiculed down to 1852, yet Mr. Williams' prophetic words became literally and exactly true within twenty years.

Here is a statement that is a little "off:"

"South of the table-land on which the Ohio Railroad is located to the

Ohio River, the country is broken with mountain ridges, dividing the water flowing north and south, and raising impassable barriers to a parallel route."

Probably the projectors of the Pittsburg, Fort Wayne & Chicago Railway never saw that, or if they did they thought Mr. Williams' zeal for the Ohio Railroad made those barriers more impassable in his mind than they really were.

Mr. Williams detailed a long list of connecting roads and canals, the most notable of which was the connection with Chicago, via the Wabash and Erie Canal.

PROPOSED PLAN AND COST OF CONSTRUCTION.

As already stated, this road was to be built upon piles or posts. These posts were 12 to 16 inches in diameter, and 7 to 28 feet long, to accommodate the inequalities in the surface of the ground. They were driven 10 feet apart, and as the road was to be double track, there were 4 rows, or 2,112 piles per mile. Upon these piles were placed longitudinally chestnut planks or sills. Then came the cross ties, 6 feet apart, requiring for both tracks 1,760 per mile. On these were placed the stringers or wooden rails, 8 × 8. Last of all came the iron ribbon, for it was little more than that, as the estimate provided for but 25 tons per mile of double track road.

The piles were driven by a machine, consisting of two sills, 30 or 40 feet long, placed parallel with each other, 7 feet apart, that being the gauge of the road. At the forward end of these sills were raised four timbers, termed leaders, 30 feet high, between which, on each side, the iron hammers, weighing half a ton each, were raised and let fall upon the pile. A circular saw attached to a shaft projecting between the leaders cut the pile to the proper grade, when the driver moved forward and the operation was repeated.

One machine employed 8 men, and drove about 140 piles—20 rods—per day.

Behind the pile driver, upon the prepared track, was a boarding home for the men employed, which traveled with the rest of the establishment.

Upon the heads of each pair of piles was fitted a tie, 8 × 8, in which a gain was cut, 9 inches wide and 4 inches deep, the tie being pinned down through this gain with a 2-inch cedar pin; but, before this was done, a half pint of salt was deposited in the auger hole of each pile, which, permeating the wood, was expected materially to preserve it from decay.

A locomotive saw-mill upon the track, run by 3 men, prepared the wooden rails at the rate of 900 lineal feet per day. That the piles were well driven is attested by the fact that many of them may be seen to-day at different points along the line. The prices in the estimated cost of the road are interesting: Iron, $80 per ton; spikes, 9 cents per pound; white oak ties, 20 cents each; timber, $7 to $8 per thousand feet. The Chief Engineer, Cyrus Williams, estimated the cost of the entire road, 177 miles, double track, at $2,653,676, about $16,000 per mile.

About one-third of the road between Cleveland and Toledo was built ready for the strap rail, but the Company succumbed to the hard times which followed the wild speculative era of 1836, and in 1843 operations

ceased before a single train had been placed upon the track and before any iron was laid. The child of the feverish speculative era of '36 died from exhaustion while its progenitors were quarreling as to the best method of rearing it. The whole scheme was generally regarded as visionary and wild, yet only ten years afterward (1853) the Cleveland & Toledo Railroad opened, and was a brilliant success from the start.

Had the Directors of the Ohio Railroad Company pushed on a little further, laid 40 or 50 miles of track, and placed trains on it, thus forming a basis for selling the Company's bonds, it can hardly be doubted that their road would now form a part of the Lake Shore & Michigan Southern Railway, and its projectors would have acquired the large fortunes reaped by others who came after them and carried out substantially the same enterprise.

In closing I wish to give credit to Clark Waggoner, Esq., the veteran editor of Toledo, for the data for a considerable portion of the sketch.

APPENDIX—"THE OHIO PLUNDER LAW."

From a history of this unique law, contributed to the Cincinnati *Enquirer* by Charles B. Flood, of Columbus, I condense a few interesting facts and figures.

The law was passed March 24, 1837, and repealed in 1840. It made the State a partner to the extent of one-third of the paid-up stock of any railroad, canal or turnpike company. For example, the Mansfield & Sandusky City Railroad had a capital of $100,000. The stockholders "paid in" $66,667, probably in "cats and dogs," and the State $33,333 in its six per cent. twenty-year bonds, taking stock in the road at par. The following roads were assisted by the State :

Mad River & Lake Erie	$293,050
Ohio Railroad	249,000
Little Miami	121,900
Vermillion & Ashland	48,450
Mansfield & Sandusky City	33,333
Fairport & Painesville	6,182
Total six railroads	$751,915
Pennsylvania & Ohio Canal	450,000
Cincinnati & Whitewater Canal	150,000
Twenty-five turnpike companies	1,853,365
Total	$3,205,280

All of which, principal and interest, was honorably paid by the State of Ohio, notwithstanding it never realized in money twenty per cent. of the investment.

The stock in the Mad River & Lake Erie Railroad (now the Cincinnati, Sandusky & Cleveland Railroad) was sold by the State, in 1866, to Rush R. Sloane at less than nine cents on the dollar, and was the initiatory step that enabled him to gain control of that road.

When the law, which was an ingenious device to make each citizen of the State who could organize a transportation company wealthy at the expense of the whole, was repealed, vast preparations were being made to make business enough to keep the bond mill at Columbus running day and night, but the repeal of the law was the heroic remedy that saved the State from being swamped.

[In the discussion which followed the reading of Mr. Leland's paper it

was stated that after more than 40 years portions of the pile and timber road-bed are still to be seen in a fair state of preservation, with the piles quite as frequently placed upon high and dry ground as upon wet, and that not only were the *fills* piled, but the *cuts* as well, the excavations being made sufficiently below grade to allow the pile heads and timber work to be wholly above ground. The question was asked if the long life of the piles might not fairly be attributed to the half pint of salt placed in each pile head.—M. E. R.]

PROCEEDINGS.

December 13, 1881:—A regular meeting was held, Vice-President Col. J. M. Wilson in the chair.

Minutes of the last meeting, and also the minutes of meetings held October 11 and November 8, 1881, were read and approved.

The petitions of Messrs. F. L. Krause, J. M. Edelman and Jno. Watterson for membership in the club, were received.

Mr. C. O. Palmer was elected an active member.

Mr. N. P. Bowler, of the firm of Bowler & Co., car wheel manufacturers, read before the Club a paper on "The Crystalization of Iron," which elicited such general interest that on motion it was made the subject of discussion for the next meeting.

Mr. H. F. Dunham, Engineer on the Connotton Valley Railroad, read a paper on "The Difficulties of Linear Measurements," citing the various methods used in making measurements on long lines, all of which are subject to errors and accidents, difficult of correction or prevention.

He suggested a method of triangulation with fixed angles, and presented a drawing of an instrument, designed by him, for use in making such measurements. The instrument consists of two telescopes, having their lines of collimation set at a fixed horizontal angle with reference to each other, and attached to a shifting bed-plate, moving in the line of both telescopes and controlled by tangent screws. Mr. Dunham illustrated the manner of using it by diagrams on the black board.

On motion the Club adjourned to meet January 10, 1882.

M. E. Rawson, Cor. Secretary.

BOSTON SOCIETY OF CIVIL ENGINEERS.

ORGANIZED 1848.

TRANSACTIONS.

FLUCTUATION OF WATER OBSERVED IN THE STAND-PIPE AT ST. LOUIS.

BY L. FREDERICK RICE, MEMBER OF THE SOCIETY.

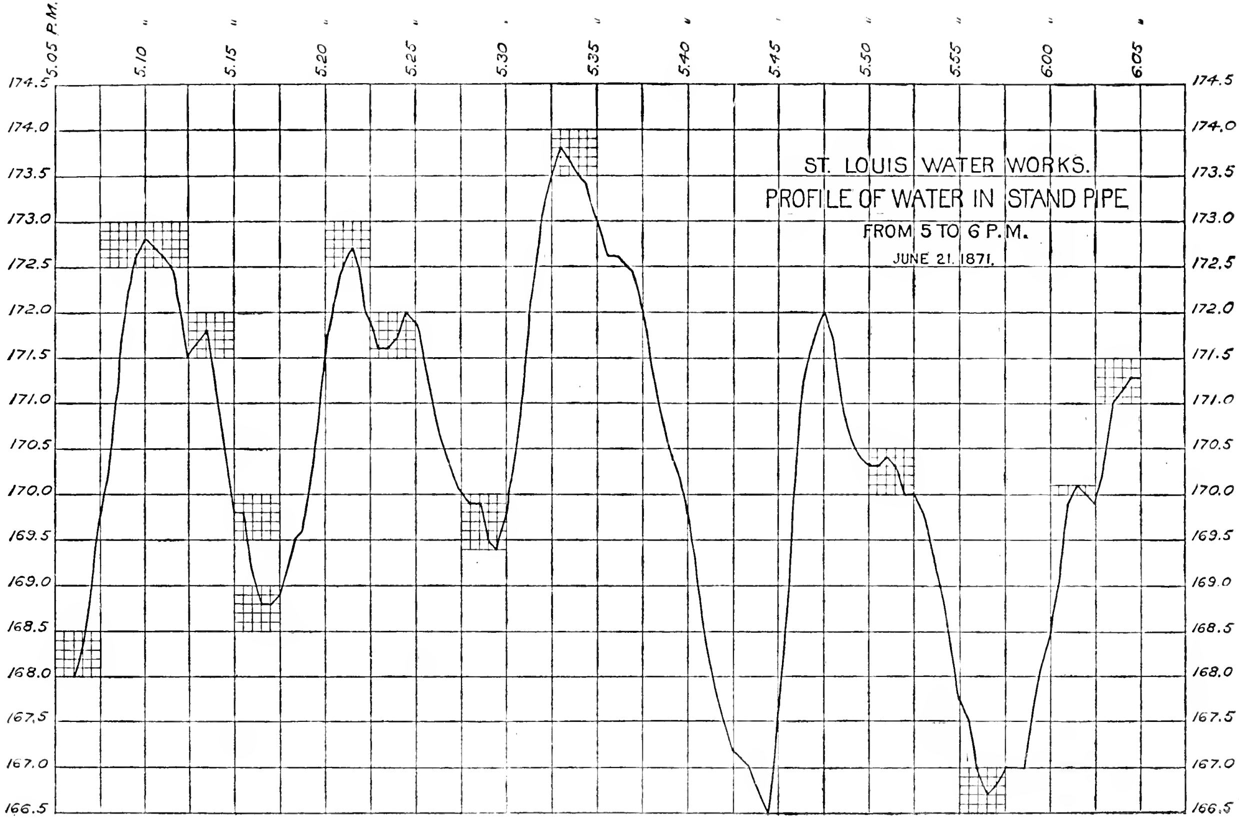
[Read November 16, 1881.]

Some peculiarities of the flow of water in pipes are here presented to the notice of the Society, in the belief that they may be of interest and in the hope that some one may be incited to a study which will result in the discovery of the cause.

In June, 1871, the writer was employed as Assistant Engineer of the St. Louis Water-Works, the extension of which had then been recently put in operation. The water, pumped from the Mississippi River, was first partially cleared from its sediment by subsidence in the settling basins, and then pumped by the high-service engines into a force main about 4½ miles in length, at the further end of which was located the Compton Hill Reservoir. At two points the force main was tapped by distribution mains, supplying the northern and central portions of the city. The surplus of water, after feeding these mains, flowed onward to the Compton Hill Reservoir, a distributing main from which supplied the southern portion of the city.

Somewhat less than a half mile from the pumps, a stand-pipe was erected upon the force main with a view to equalizing the work of the pumps and the flow through the pipes. The pumps were located on the low ground bordering the river, only a few feet above high-water mark. The stand-pipe was on the summit of the bluff, nearly a hundred feet higher—and between them, near the foot of the bluff, was a check-valve in the main.

Soon after the works went into operation, the writer, desiring to ascertain the height to which the water rose in the stand-pipe, and to determine the actual head necessary to overcome the friction in the pipe modified by the flow through the intercepting distribution mains, arranged a float in the stand-pipe, with an indicator which admitted of easy ob-



ST. LOUIS WATER WORKS.
PROFILE OF WATER IN STAND PIPE
FROM 5 TO 6 P.M.
JUNE 21. 1871.
5.05 P.M.
5.10
5.15
5.20
5.25
5.30
5.35
5.40
5.45
5.50
5.55
6.00
6.05
174.5
174.0
173.5
173.0
172.5
172.0
171.5
171.0
170.5
170.0
169.5
169.0
168.5
168.0
167.5
167.0
166.5

servation from the outside. An inspection of this indicator showed that the water surface did not, as had been anticipated, remain at an approximately constant height when the pumps were in uniform motion, but rose and fell through a space of several feet—7 to 8. It was further noticed that these oscillations were periodical, several occurring each hour at intervals not very dissimilar.

To learn the peculiarities of this oscillation careful observations were made on the 21st of June, 1871, from 5 to 6 o'clock P. M., as rapidly as they could be recorded, and a profile of the result was prepared and is herewith presented. The horizontal spaces represent the *time* of each observation, reading to half minutes. The vertical spaces show the *elevation* of the water surface within the stand-pipe above the city directrix, reading to feet and tenths.

It will be observed that the profile shows five summits and five valleys or depressions, indicating four and a half complete waves or oscillations, and that the heights of the waves, measured from a mean of the valleys adjacent to each summit, vary from 3.6 to 5.8 feet; the distance of the highest summit above the lowest valley (which was also an adjoining one) was 7.3 feet. The four complete oscillations occupied 50½ minutes—an average duration of 12.6 minutes. The shortest time of pulsation was 11 minutes (there were two of these) and the longest 15 minutes; the other being 12.5, the exact average. The summits were reached at intervals of 11.5, 11.5 and 14.5 minutes.

A noticeable peculiarity in the profile shows that while the water *rose* at a nearly uniform rate, and in a space of from 3 to 4½ minutes, its *fall* was interrupted at from 1.2 to 1.7 foot below the summits (in three instances a slight rise of from .1 to .5 foot taking place), and then completed, occupying from 6.5 to 11.5 minutes.

The writer would be glad to explain the cause of this peculiar profile, but pressure of professional duties prevented his making additional observations during his connection with the works, and he is not aware that any have been made since that time.

The single profile is therefore presented without any accompanying theory of explanation, but perhaps not fruitlessly if it should stimulate further investigation.

SOME TESTS MADE ON SPECIMENS OF BRICKS USED IN ARCHING THE HOOSAC TUNNEL.

BY THOMAS DOANE, MEMBER OF THE SOCIETY.

[Read January 18, 1882.]

At the time the Hoosac Tunnel was being arched in those parts in which the rock roof was not sufficiently stable, the writer made some tests of the bricks which were being used, and of others which could at that time be obtained and which were thought to be more suitable. They may, perhaps, have a scientific interest for some, and may help to illustrate the foolishness of political control of public works.

No. of experiment.	Place of manufacture.	Size. Thickness.	Width.	Length.	Contents in cu. inches.	Weight dry.	Weight wet.	Weight in water when saturated.	Weight in water when dry.	Specific gravity.	Increase in weight when wet in per ct. of dry weight.	Per cent. of porosity or cavities as compared with whole bulk.	Cubic inches in brick, calculated from displacement of water.	Per cent. of porosity or cavities as compared with whole brick as recalculated by displacement.	Averages of full number of each kind.
						lb. oz.	lb. oz.								
1	Troy, N. Y.....	2.30	3.60	8.00	66.24	4-0	4-13	2-6½	1-9½	1.66	0.203	0.339	66.53	0.339	Cu. in.........67.68
2	"	2.25	3.65	8.15	66.93	4-1	4-14	2-7	1-10	1.67	0.200	0.336	67.39	0.333	Sp. gr.......... 1.67
3	"	2.35	3.65	8.10	69.48	4-1½	4-14½	2-7½	1-10½	1.68	0.198	0.323	67.39	0.333	Inc. in weight.. 0.20
4	"	2.40	3.65	8.20	71.83	4-2½	5-0	2-8	1-10½	1.66	0.203	0.324	69.12	0.337	Porosity....... 0.34
5	"	2.35	3.70	8.15	70.86	4-2½	5-0	2-8	1-10½	1.66	0.203	0.329	69.12	0.337	
6	"	2.40	3.65	8.05	70.52	4-0	4-13½	2-7	1-9½	1.66	0.211	0.316	66.53	0.351	
7	Medford, Mass.	2.25	3.30	7.90	58.66	4-7½	4-12	2-10½	2-6	2.13	0.063	0.132	57.89	0.134	Cu. in....... 54.25
8	" "	2.25	3.30	7.80	57.91	4-9	4-13	2-11½	2-7½	2.18	0.055	0.119	57.88	0.119	Sp. gr.......... 2.1
9	Fresh Pond, "	2.10	3.30	7.55	52.32	4-6½	4-4	2-6	2-2½	2.15	0.054	0.116	51.84	0.116	Inc. in weight. 0.07
10	" "	2.10	3.30	7.65	53.01	3-14½	4-3½	2-5½	2-0½	2.08	0.080	0.163	51.84	0.166	Porosity....... 0.14
11	" "	2.10	3.35	7.80	54.87	3-15	4-4½	2-6	2-0½	2.07	0.087	0.173	52.50	0.181	
12	" "	2.10	3.35	7.50	52.76	4-0	4-4	2-5	2-1	2.07	0.062	0.131	53.57	0.129	
13	West End......	2.40	3.50	8.10	68.04	3-15½	4-12½	2-6½	1-9½	1.67	0.205	0.330	65.66	0.342	Cu. in........ 61.62
14	"	2.30	3.50	8.00	64.40	3-13½	4-8	2-5	1-10½	1.77	0.171	0.255	60.48	0.300	Sp. gr... ..... 1.76
15	"	2.25	3.45	8.00	62.10	3-15	4-9	2-6	1-12	1.80	0.158	0.278	60.48	0.285	Inc. in weight. 0.17
16	"	2.35	3.50	7.95	65.39	3-15½	4-10	2-6½	1-12	1.79	0.165	0.277	61.34	0.295	Porosity 6.30
17	"	2.25	3.50	8.00	63.00	3-14½	4-8½	2-5½	1-11½	1.79	0.160	0.274	60.48	0.285	
18	"	2.30	3.50	7.95	64.00	3-14½	4-9	2-5½	1-11	1.76	0.168	0.283	61.34	0.295	
19	Montague	2.40	3.60	8.00	69.12	4-5½	5-0½	2-8	1-12	1.67	0.158	0.275	71.71	0.265	Cu. in 64.15
20	"	2.30	3.35	7.80	60.10	4-4½	4-11	2-7½	2-1	1.93	0.094	0.186	61.34	0.183	Sp. gr.......... 1.83
21	"	2.15	3.45	7.70	57.11	4-2½	4-7½	2-6½	2-1½	2.02	0.075	0.151	57.02	0.151	Inc. in weight.. 0.12
22	"	2.40	3.60	7.90	68.26	4-4	4-15	2-7½	1-12½	1.72	0.162	0.279	68.26	0.278	Porosity..... . 0.22
23	"	2.30	3.50	7.80	62.79	4-3½	4-12	2-7½	1-15	1.85	0.126	0.234	63.07	0.233	
24	"	2.40	3.50	7.85	65.94	4-5	4-14	2-7½	1-14½	1.79	0.130	0.236	66.53	0.234	
25	Easthampton .	2.25	3.50	7.90	62.21	4-4	4-10	2-6½	2-0½	1.91	0.088	0.166	61.34	0.169	Cu. in....... 61.77
26	" .	2.20	3.55	7.80	60.92	4-1½	4-9½	2-5½	1-13½	1.82	0.122	0.226	62.20	0.222	Sp. gr... .... 1.89
27	" .	2.20	3.60	7.90	62.57	4-2½	4-12	2-7	1-13½	1.80	0.143	0.262	63.94	0.256	Inc. in weight. 0.11
28	" .	2.15	3.50	7.95	59.82	4-3	4-9½	2-6½	2-0	1.91	0.097	0.188	60.48	0.184	Porosity....... 0.20
29	" .	2.20	3.40	7.65	57.22	3-15	4-4½	2-3	1-13½	1.88	0.087	0.166	57.88	0.165	
30	" .	2.25	3.60	8.00	64.80	4-5½	4-14	2-8½	2-0	2.01	0.122	0.226	64.80	0.227	
31	Newburyport..	2.10	3.35	7.60	......	4-0	4-5	2-5	2-0	2.00	0.078	....	55.30	0.156	Cu. in.........53.14
32	" ..	2.15	3.25	7.55	......	3-14½	4-3	2-5	2-0½	2.08	0.072	....	51.84	0.144	Sp. gr......... 2.09
33	" ..	2.05	3.05	7.20	......	3-14	3-15	2-4½	2-3½	2.34	0.016	....	45.79	0.038	Inc. in weight. 0.07
34	" ..	2.25	3.40	7.70	......	3-15	4-5	2-5	1-15	1.97	0.095	....	55.30	0.187	Porosity. 0.14
35	" ..	2.10	3.30	7.60		4-1	4-5	2-6	2-2	2.10	0.061	....	53.57	0.110	
36	" ..	2.05	3.20	7.35	......	3-14½	4-0½	2-5	2-3	2.27	0.032	....	47.52	0.072	
37	" ..	2.20	3.50	7.75	......	4-5	4-12	2-9	2-2	1.97	0.101	....	60.48	0.200	
38	" ..	2.20	3.35	7.65	......	3-15½	4-5½	2-5¼	1-15½	1.98	0.094	....	55.30	0.187	

Prof. Rankine, in his Civil Engineering, page 366, says:

"The following are characteristics of good bricks:

"To be regular in shape, with plane parallel surfaces and sharp right-angled edges.

"To give a clear, ringing sound when struck.

"When broken to show a compact uniform structure, hard and somewhat glassy, and free from air bubbles and cracks.

"Not to absorb more than about $\frac{1}{15}$th of their weight of water (which is equal to 0.0666 of weight).

"Bricks which answer the preceding description, when set on end in a hydraulic press, should require at least 1,100 lbs. on the square inch to crush them, agreeably to the strength of 'strong red bricks' as stated in the table at the end of this volume, and they will sometimes bear considerably more.

"The weaker qualities of bricks may be estimated as having from $\frac{1}{2}$ to $\frac{2}{3}$ of the strength above stated.

"The bricks supplied for every building of importance should be carefully inspected, and the defective ones thrown away."

The Boston Water-works was supplied with brick under substantially the above specifications.

The tests made were as to size, character of sound when struck together, internal structure and appearance, absorption of water and porosity, and specific gravity. The work was not *considered* sufficiently important to justify experiments to determine their strength.

When specimens were selected for test, six average specimens of each maker were taken, excluding imperfect ones, and at that time no others than brick from Montague, Easthampton and Troy were being used in the tunnel arches. The others in the table were taken as being probably better for tunnel use than the others, and because they could then be had on or near the line of the Fitchburg Railroad.

The following is a table covering the three kinds of brick being used in the tunnel, and another kind entirely suitable for the work and most easily obtained:

Rankine's requirements.	Clear, ringing sound.	Uniform structure, hard and glassy.	Absorption of water not to exceed 0.066 per ct. of weight.	Specific gravity 2 to 2.167.
Montague bricks	Good ring in some, in others wanting	Fair	0.124	1.83
Easthampton bricks	None whatever	Sandy and rotten	0.110	1.89
Troy bricks	Very little ring, not good	Not uniform in structure and rotten.	0.203	1.66
Medford bricks	Clear, ringing sound	Uniform structure, hard and glassy.	0.067	2.11

The above results are the averages of the six specimens of each make.

The Boston Water-works excludes bricks which have cavities amounting to more than 15 per cent. of the whole brick.

Cavities in Montague brick equal	22.4	per cent.
" " Easthampton " "	20.4	"
" " Troy " "	33.8	"
" " Medford " "	14.1	"

From these tables it will be seen that the *Montague* bricks came the nearest to Rankine's requirements of *any used in the tunnel*, though they fall far short, having double the absorption they should have, and falling much below in specific gravity.

The *Easthampton* bricks stood about the same as the Montague as to absorption and specific gravity, but they were otherwise very inferior. They wanted in strength, most manifestly, a dozen in succession having been broken by a blow of the foot when lying with their ends resting upon two others. This can rarely be done in the case of good bricks. They can also be easily cut with a knife, and also be ground into a powder. They will probably fall to pieces under the continued action of water. Nor can a water-tight piece of work be made with them.

The *Troy* bricks have little ring, which is not good and clear. They are not so rotten as the Easthampton bricks, but are very inferior as to absorption of water and specific gravity.

The *Medford* bricks are the only ones of the four kinds embraced in the latter table which came anywhere near the requirements.

The *probability* is that, had tests of strength been made, most of the Montague bricks and all of the Easthampton and Troy bricks would have fallen *far short* of the Medford bricks—say one-half.

PROCEEDINGS.

JANUARY 18, 1882:—A regular meeting of the Society was held this evening President Doane in the chair and ten members present.

The record of the last meeting was read and approved.

The government reported on the matter of a proposed change in the evening and place of holding the meetings; that they had submitted the questions to the members for an expression of their preferences by an informal letter-ballot and the result was as follows: In favor of changing place of meeting to Institute of Technology, yes, 10; no, 39; no preference, 10.

Third Thursday in the month as convenient as third Wednesday: Yes, 51; no, 8. The report was accepted and placed on file.

Notice was given in writing of a proposed amendment to the first by-law, so that it shall read: The regular meeting of the Society shall be held on the evening of the third Thursday in every month.

Mr. George F. Swain was elected a member of the society, and the following were proposed for membership: Prof. Gaetano Lanza, by Messrs. Channing Whitaker and Thomas Doane; and Mr. Isaac M. Story, by Messrs. R. E. Woodward and E. S. Shaw.

Reports upon articles of interest were made by Mr. Carson from "Annales des Ponts et Chaussées;" by Mr. French from the Journal of the Franklin Institute and Mr. Blodgett from *The Electrician*.

President Doane spoke of some experiments he had made on the bricks which were furnished at the time the Hoosac Tunnel was being arched, and a table showing the results was presented.

[*Adjourned.*] S. E. TINKHAM, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

ORGANIZED 1868.

TRANSACTIONS.

DIAGRAM FOR FACILITATING THE CALCULATION OF VELOCITY AND DISCHARGE OF SEWERS.

By Wm. Paul Gerhard, Member of the Club.

[Read January 10, 1882.]

In designing a system of sewers one of the many problems to be solved is to determine their sizes. This is strictly a question of hydraulics, and its solution is readily accomplished by means of formulæ and calculations, or by tables worked out so as to facilitate the arithmetic operations. Very complete tables of the velocities and discharges of sewers are given in Baldwin Latham's "Sanitary Engineering."

In preparing estimates or making preliminary plans, however, it becomes desirable to have the relation between inclination, size, velocity and discharge of a sewer in a shape which may permit, at a glance, finding two of the above quantities if the other two are given.

A diagram, constructed so as to illustrate the relation of these four quantities, will best serve for this purpose, and the annexed graphical solution of the problem (for whose suggestion the writer is under obligations to M. L. Holman, Esq., Assistant Engineer St. Louis Water-works) is offered to meet such a want.

This diagram is based upon Baldwin Latham's Tables, calculated from Weisbach's formula :

$$v = \frac{\sqrt{2\,gh}}{\sqrt{1 + e + c\,\frac{l}{d}}} \qquad \text{wherein}$$

h = head of water in feet.
l = length of sewer in feet.
d = diameter of sewer in feet.
v = velocity in feet per second.
c = coefficient for friction in pipes.
e = coefficient of resistance for entrance.
g = acceleration of gravity=32.2 .

The coefficient e may be assumed according to Weisbach as=.505 in the average.

The coefficient c is somewhat variable with the square root of the velocity, viz :

$$c = .01439 + \frac{.016921}{\sqrt{v}}$$

With a velocity v and the diameter d the discharge is accordingly found by the formula:

$$Q = v \times \pi \frac{d^2}{4}$$

Q being discharge in cubic feet per second, the sewer running full.

If we assume the sewer running only *half full*, the discharge per *minute* becomes

$$Q = \tfrac{1}{2}\, v \times 60 \times \frac{\pi d^2}{4} \quad \text{cubic feet.}$$

The diagram is constructed for circular sewers from 3 to 36 inches diameter. Its enlargement, to include sewers of greater sizes, could easily be accomplished, although it would be better to construct a second diagram for such purpose, ranging from a diameter of 1 foot to a diameter of 20 feet.

The diagram gives the discharge for sewers running *half full*. It is, however, equally serviceable, assuming the sewer running full, as the hydraulic mean radius, *i. e.*, $\frac{\text{sectional area of waterway}}{\text{wetted perimeter}}$, and consequently the velocity is the same in both cases. The discharge Q is therefore simply double the value found in the diagram.

The diameters are plotted as *abscisses*, the velocities as *ordinates*.

The first set of curves, all of which pass through the zero point, represents various grades of the sewer.

The second set of curves (being functions of $\sqrt{d^5}$) represents the discharges of the sewer for different diameters and velocities.*

It may be well to mention that the numerical values of Latham's Tables are strictly applicable only to a length of the sewer equal to the rate of the inclination multiplied by the velocity; but for approximate results, such as are required in preliminary estimates, the error arising from adapting the value to any length of sewer is too small to be considered.

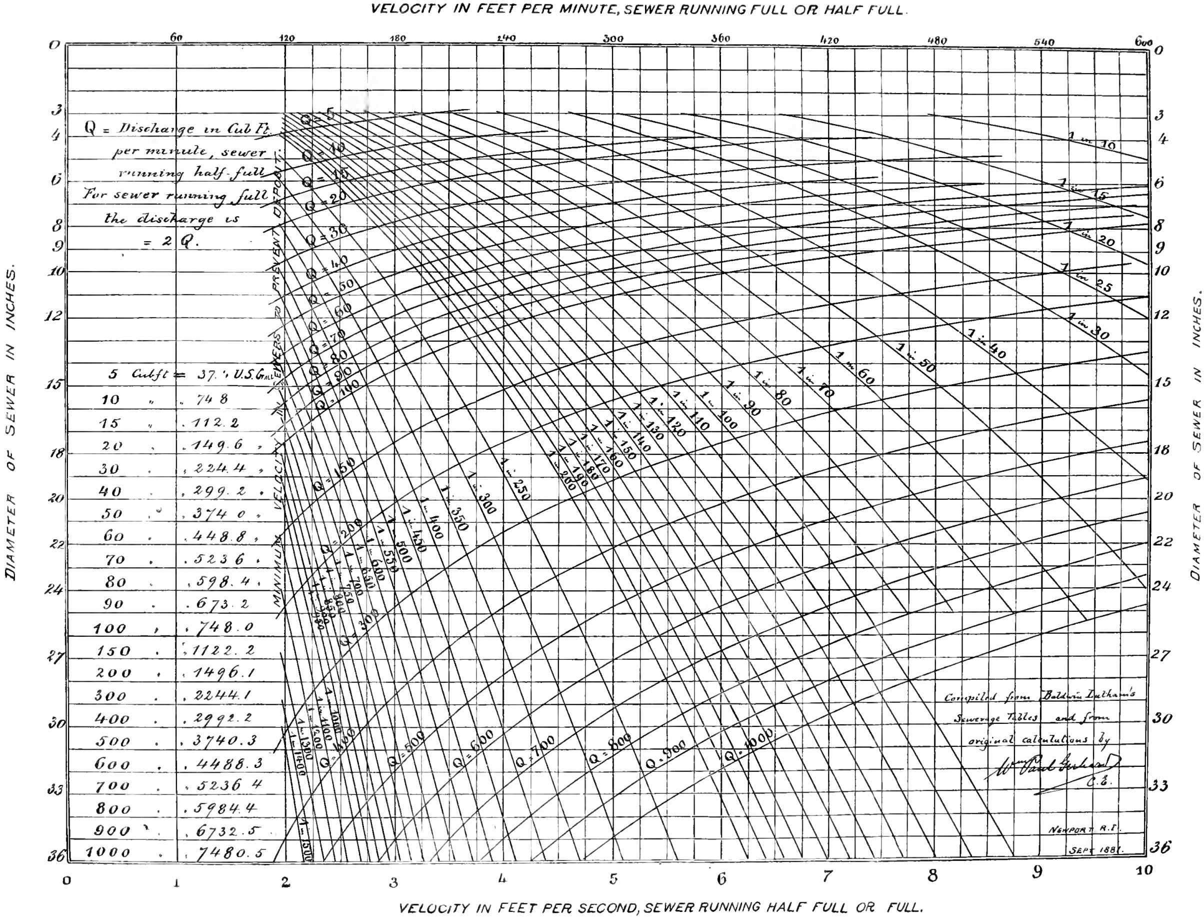
With the four quantities

Q = discharge,
v = velocity,
i = rate of inclination = $\frac{h}{l}$.
d = diameter,

the following six different problems may arise (being the possible combination of four elements by two); viz. :

1. Given Q and i to find d and v.
2. " d " i " " Q " v.
3. " Q " v " " d " i.
4. " d " v " " Q " i.
5. " Q " d " " i " v.
6. " v " i " " Q " d.

* In a paper "The flow of water in small channels," etc., Mr. Rudolph Hering, C. E., has calculated and constructed similar diagrams for sewer calculations, based upon the improved formulas for velocity of Ganguillet and Kutter. Mr. Hering plots the grades


VELOCITY IN FEET PER MINUTE, SEWER RUNNING FULL OR HALF FULL.
60
120
180
240
300
360
420
480
540
600
DIAMETER OF SEWER IN INCHES.
Q = Discharge in Cub Ft. per minute, sewer running half-full
For sewer running full the discharge is = 2 Q.
5 Cub ft = 37.4 U.S. Galls
10 " 74.8
15 " 112.2
20 " 149.6 "
30 " 224.4 "
40 " 299.2 "
50 " 374.0 "
60 " 448.8 "
70 " 523.6 "
80 " 598.4 "
90 " 673.2 "
100 " 748.0 "
150 " 1122.2 "
200 " 1496.1 "
300 " 2244.1 "
400 " 2992.2 "
500 " 3740.3 "
600 " 4488.3 "
700 " 5236.4 "
800 " 5984.4 "
900 " 6732.5 "
1000 " 7480.5 "
MINIMUM VELOCITY IN SEWERS TO PREVENT DEPOSIT.
Q = 5
Q = 10
Q = 15
Q = 20
Q = 30
Q = 40
Q = 50
Q = 60
Q = 70
Q = 80
Q = 90
Q = 100
Q = 150
Q = 200
Q = 300
Q = 400
Q = 500
Q = 600
Q = 700
Q = 800
Q = 900
Q = 1000
1 in 10
1 in 15
1 in 20
1 in 25
1 in 30
1 in 40
1 in 50
1 in 60
1 in 70
1 in 80
1 in 90
1 in 100
1 in 110
1 in 120
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1 in 350
1 in 400
1 in 450
1 in 500
1 in 550
1 in 600
1 in 650
1 in 700
1 in 750
1 in 800
1 in 850
1 in 900
1 in 950
1 in 1000
1 in 1100
1 in 1200
1 in 1300
1 in 1400
1 in 1500
Compiled from Baldwin Latham's Sewerage Tables and from original calculations by
Wm Paul Gerhard C.E.
NEWPORT R.I.
SEPT 1881.
0 1 2 3 4 5 6 7 8 9 10
VELOCITY IN FEET PER SECOND, SEWER RUNNING HALF FULL OR FULL.

The first and second cases are those most frequently occurring.

In order to illustrate the use of the diagram, an example is given below for each case.

Problem 1.—Given the inclination of a sewer to be 1 in 250, and the discharge (if running half full) 200 cubic feet per minute, what will be the diameter of the sewer and what the velocity of flow in it?

Answer.—Turning to the diagram, and following the two curves Q and i to their point of intersection, we find, by going from this point horizontally to the end of the line, the required size to be 17.75 inches diameter, and by going vertically upwards we find the velocity to be about 3.9 feet per second.

If the same discharge should be effected by a sewer running *full*, we divide first Q by 2, and look into the diagram for the intersection of $i = 1$ in 250 and $Q = 100$ cubic feet. In this case the required size would be $d = 13.5$ inches, and the velocity $v =$ about 3.35 feet per second.

Problem 2.—How much water does a 6-inch house-drain deliver per minute, running half full, and laid at an inclination of 1 in 100, and what would be the velocity of the water?

Answer.—The intersection of the horizontal line at the diameter 6 inches and the inclination curve 1 in 100 falls between the curves $Q = 20$ and $Q = 30$, and is found by interpolation to be about 21 cubic feet per minute. By going vertically upward from the point of intersection we find the velocity to be a little over 3.5 feet per second.

Problem 3.—What is the size of pipe necessary to deliver 40 cubic feet per minute (running half full) with a velocity of 3 feet per second, what inclination should be given to the pipe?

Answer.—At the intersection of the curve $Q = 40$ and the vertical line $v = 3$ feet, we find the diameter $= 9$ inches, and the inclination between 1 in 200 and 1 in 250, say 1 in 210.

Problem 4.—How much water will a 12-inch pipe, the flow being at the rate of 2.5 feet per second, running half full, discharge per minute? What inclination should it have?

Answer.—The intersection of the vertical lines $v = 2.5$ and horizontal line $d = 12$ inches gives the discharge to be between $Q = 50$ and 60, say 58 cubic feet per minute, and the grade to be between 1 in 350 and 1 in 400, say 1 in 380.

Problem 5.—Given $Q = 400$ cubic feet per minute, $d = 24$ inches, what is i and v?

Answer.—The intersection of $Q = 400$ and $d = 24$ falls between the inclination curves $i = 1$ in 250, and 1 in 300, by interpolation $i = 1$ in 280. The velocity is found by going from the point of intersection vertically upward; it is $v = 4.25$ feet per second.

Problem 6.—Given $v = 3$ feet per second, $i = 1$ in 90, what is d and Q?

Answer.—The intersection of the vertical line $v = 3$ and the curve $i = 1$ in 90, gives Q between 5 and 10, say about 8 cubic feet per minute, and the diameter to be very nearly 4 inches.

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as ordinates, the discharges as abscisses. In that case the velocities are represented by curves, and the diameters by straight lines, all passing through the zero point of the co-ordinate system.

SPECIFICATIONS FOR LOCOMOTIVE (152) WABASH, ST. LOUIS & PACIFIC RAILWAY.

By Jacob Johann, Member of the Society.

[Reprinted from the *National Car-Builder* of January, 1882.]

GENERAL DIMENSIONS.

Cylinders	17 × 24 inches.
Driving wheels, diameter	5 ft. 9½ "
Inlet ports	1¼ × 12¼ "
Steam ports	1¼ × 16 "
Exhaust ports	3 × 16 "
Width of bridges	1¼ "
Tank capacity	3,000 gallons.
Weight on drivers	51,000 pounds.
Weight of engine with 3 gauges of water	80,000 "

Boiler and fire-box of steel, flues of iron. Fuel, soft coal.

Boiler.—Straight top: and made throughout of best homogeneous steel plates $\frac{7}{16}$ inch thick (unless otherwise specified) and riveted with ¾-inch rivets, spaced not over 1⅞-inches between centres. All longitudinal seams double riveted and welted, all circular seams single riveted and welted around the bottom to above water line.

Pressure.—150 pounds to square inch.

Waist.—Inside diameter at smoke-box end 52 inches, and at fire-box end 53¾ inches. Side sheets of fire-box shell ⅜-inch in thickness, and extending to the top, forming a butt joint at the crown, and over these an extra crown sheet ⅜ of an inch in thickness is placed, extending down far enough on each side to receive all the fire-box crown stays. This extra crown sheet is riveted to the side sheets on each side of the butt joint formed by them at the crown, and near the lower edges of this extra sheet. Dome 28 inches in diameter inside, and 28 inches high above boiler, fitted with cast-iron ring and cover so arranged with slotted flanges that bolts may be used instead of studs. Centre line of dome situated 7 feet 7 inches ahead of the back face of back head of boiler, the placing of the dome so far ahead being necessitated by the system of staying employed.

Smoke-box is 52⅞ inches in diameter inside, and 33 inches long from centre line of rivets securing the junction between the smoke-box and waist and the front end. Length over all, 20 feet 6 inches.

Tubes.—Of No. 11 lap-welded charcoal iron, with copper ferrules at both ends. Tubes, 160 in number, 2 inches outside diameter—11 feet 6 inches long, separated by ¾-inch bridges in fire-box flue sheet, and ⅞-inch bridges in front of flue sheet, to provide for a more perfect water circulation.

Fire-box.—Of steel, arched and sloping, with round corners, box 66 inches long and 34⅜ inches wide inside, height (sloping 1 inch to the foot) 70 inches in front, 64½ inches back, inside measure. All plates thoroughly annealed after flanging. Flue sheet ½-inch, crown sheet ⅜-inch, side and fire-door sheets $\frac{5}{16}$-inch thick. Water spaces 3½ inches all around at the mud ring, increasing to 4 inches near the crown sheet, this increase being made by closing in the side and fire-door sheets for the sides and back, and by setting out the throat sheet for the front. Stay bolts are ⅞ inch in diameter; screwed in and riveted to sheets and not over 4½ inches

from centre to centre. Fire-door opening formed by a special oval ring riveted to the outside and inside sheets by flanging both sheets outward.

Crown Staying.—Crown sheet arched transversely with a radius of 35 inches, with round corners of 13-inch radius at flue-sheet end, and 10-inch radius at fire-door sheet end. Crown stays of 1 inch Sligo iron upset at one end to admit of a $\frac{1}{8}$-inch thread: spaced longitudinally $4\frac{7}{8}$ inches and transversely $5\frac{1}{2}$ inches apart on crown sheet. The stay holes in the boiler crown are so located that the stays enter both the inside and outside crowns at the same angle longitudinally: the obliquity at which they enter the outside crown transversely, especially the lower rows, being compensated for by the double sheets forming the outside crown. Even the stay having the greatest obliquity is by this means provided with ample thread connection in the boiler crown. The fire-box crown is tapped out to 1-inch thread, and the boiler crown to $1\frac{1}{8}$ inches thread, the number of threads to the inch being the same in each case, special taps and reamers being employed for the purpose. The stays, after being screwed into place, are cut off within $\frac{3}{16}$ of an inch of the inside and outside crowns, and riveted over with a few well-directed blows of the hammer.

Boiler Staying.—The back head and front flue sheet is well stayed by angle gusset braces made of $\frac{7}{16}$-inch steel plates, the double angle iron connections for these braces also being made of the same material, as they answer the purpose much better than if made of merchant angle iron.

Cleaning Arrangements.—Cylinder part of boiler is fitted with Johann's boiler washer immediately back of front flue sheet, with a man-hole just back of washer for convenience in examining boiler. Cleaning plugs in corner of fire-box. Hand-hole plates in front leg, and blow-off cock in back end.

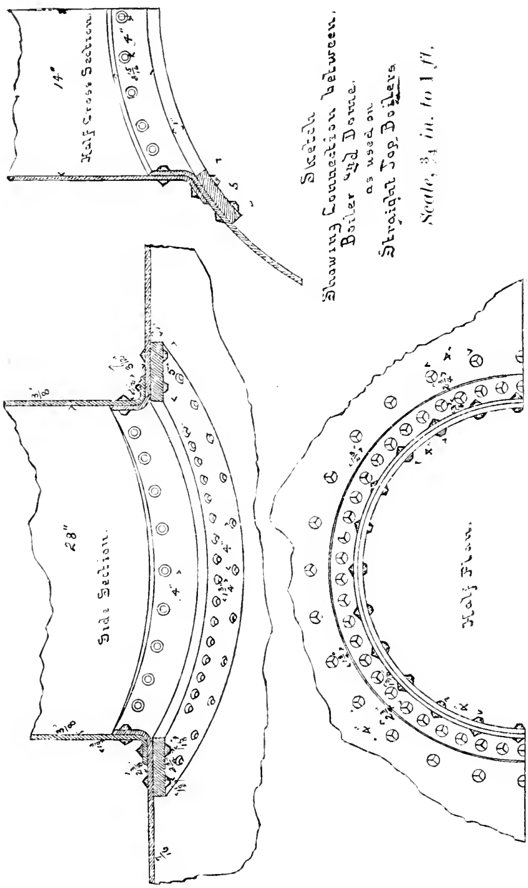
Throttle.—Balance poppet throttle valve of cast iron. Throttle pipe of cast iron, with a flange or water-shed cast on with it, to prevent the water from following steam along the pipe. Dry pipe of wrought iron, 6 inches inside diameter.

Grates.—Of the cast-iron rocking finger grate pattern arranged to work from cab. Fingers $9\frac{1}{4}$ inches long from centre of grate to the end of fingers. Ash pan fitted with double dampers.

Smoke Stack.—Diamond shape; top 15 feet above top of rail.

Frames.—Material, best hammered iron. Dimensions, 51 inches from outside to outside: bars $3\frac{1}{2}$ inches wide throughout, $4\frac{1}{2}$ inches deep between pedestal, 8 feet between pedestal centres, 3 feet $4\frac{1}{2}$ inches from centre of back pedestal to back end of frame, 4 feet 1 inch from centre of forward pedestal to front end of connection. Length of pedestal limbs over all, $23\frac{1}{2}$ inches: pedestal limbs secured together by wrought-iron pedestal braces, $2\frac{1}{2} \times 3\frac{1}{2}$ inches, securely bolted to lower bar of frame. Front limbs of all pedestals are at right angles to centre line of motion, back limbs tapering 1 inch to the foot—all limbs being fitted with flanged wedges and shoes, the back ones being movable. Length of back frames over all, 15 feet $5\frac{1}{2}$ inches. Forward frames, $3\frac{1}{2}$ inches wide 4 inches deep: length of forward frames, 14 feet $2\frac{1}{2}$ inches over all: length of forward and back frames after connection is made, 26 feet $4\frac{1}{2}$ inches. Top of forward frames to set $12\frac{1}{2}$ inches below top of back frames.

Cylinders.—Of best close grained cast iron, one cylinder and half saddle being cast in one piece. Right and left cylinders are reversible and interchangeable. Distance from centre to centre of cylinders, 6 feet 2 inches : valve faces raised 1 inch above steam chest seat to allow for wear. Oil valves are placed in cab and connected to steam chests by pipes running



under the jacket. Pipes of seamless brass tubing, proved to 200 pounds pressure.

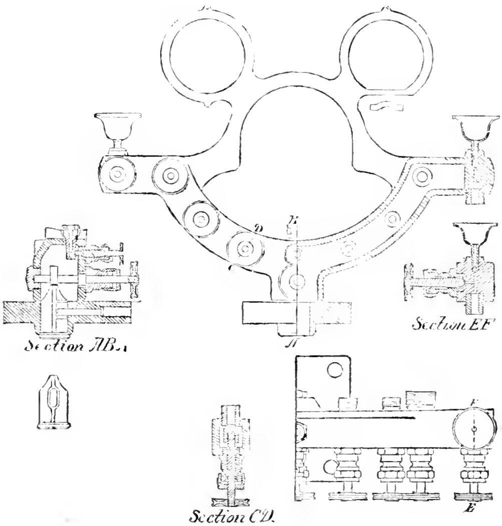
Pistons.—Heads and followers of cast iron, fitted with self-adjusting cast-iron rings. Piston rods of steel 2⅝ inches in diameter, ground and keyed to cross-heads and riveted to piston.

Guides.—Of wrought iron, case-hardened, securely fitted at back ends to a wrought-iron guide-yoke, which is 1 by 8 inches between frames, and has no connection with boiler.

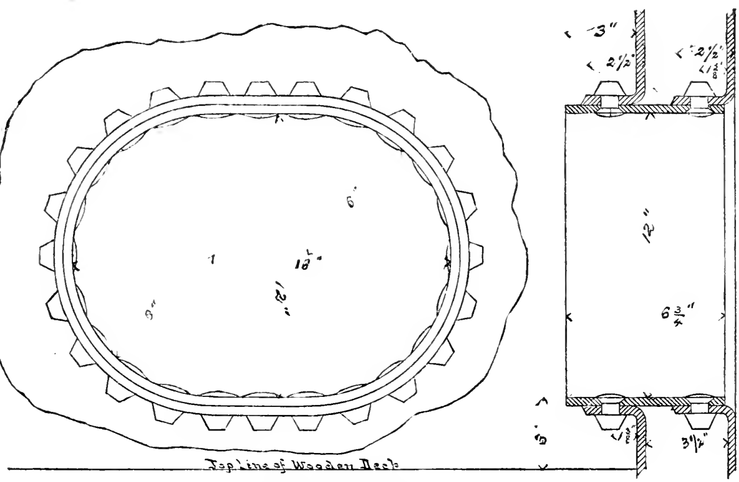
Cross-heads.—Of cast-steel, with Babbitted bearings : length of bearing,

16 inches: wrist pins separate from cross-head, and of steel, and are pressed into position, being held from turning by a feather.

Link Motion.—Is the ordinary shifting link. The link blocks, saddles



Scale, ——.



Scale, 1½ *in. to* **1** *ft.*

and pins are of hammered iron, case-hardened steel bushings being used on all parts of valve motion where it is possible to do so, and all bearings that work in them are of steel or wrought iron, case hardened. The link is solid, 23 inches long over all; block opening, $2\frac{1}{4}$ inches; section of link, $1\frac{1}{4} \times 2\frac{1}{4}$ inches wide; radius of link, 60 inches; distance from

centre to centre of blade pins, 13 inches: centre of saddle pin is on link arc and 3 inches above horizontal centre of link. Link block bearing, 5½ inches long, with wide flanges to give increased wearing surface. Length of hanger from centre to centre, 10 inches: length of lifting arm, 21½ inches. Rocker shaft of cast steel, bearing being 4 inches in diameter by 10¾ inches in length. Lower arm 10 inches, and upper arm 10½ inches long from centre to centre. Reversing shaft of wrought iron with arms forged on.

Valves.—Plain slide: outside lap, ¾ inch: inside lap, line and line: valve lead 1/16 inch at full stroke. Greatest travel, 5¼ inches.

Driving Wheels.—Four in number, 69½ inches in diameter: centres of cast iron with hollow rims, spokes and hubs, and turned to 62½ inches in diameter to receive tire. Tire, 3½ inches thick, when finished 5½ inches wide. Distance between inside of driving-wheel hubs when placed on axles 54¼ inches. Axles of cast steel: journals, 7 inches diameter and 8 inches long: wheel seat, 6⅞ inches diameter by 7 inches in length: eccentrics, 5 inches throw, 14¾ inches outside diameter, 3¼ inches wide, with a tongue 2½ inches wide and ⅜ inch deep. Eccentric straps of cast-iron, parting at an angle of 45 degrees to a horizontal line, provided with an oil cup on top and an oil cellar in the bottom: space for eccentric blade planed out to receive end of blade, which is 3½ inches wide and 1 inch thick. Driving boxes of cast iron, with brass bearings Babbitted: saddle of cast steel and separate from boxes. Driving springs of best cast steel, tempered in oil: springs 36 inches long over all, and composed of 8½-inch leaves, 3½ inches wide. Steel roller connection between saddle and spring band.

Rods.—Of the best hammered iron and of I section between stub ends, planed throughout and furnished with all necessary straps, keys and brasses. Main rod 7 feet 6½ inches long between centres; front bearing, 3 inches in diameter and 3 inches in length; back bearing, 4 × 3¾ inches: side rods, 8 feet long between centres; bearings, 3 inches in diameter, 3¼ inches long: crank pins, of cast steel, 4¼ inches in diameter in hub seat.

Feed Water.—Supplied by two No. 16½ Rue injectors placed inside of cab, one on each side of boiler, water entering the boiler through check valves placed 22 inches back of the front flue sheet.

Steam Gauge Stand.—All steam used for the various purposes on the engine is obtained from one opening in the boiler through the intervention of a steam gauge stand. This stand is secured to the boiler by a heavy flange and four studs, the stand being weakened just above the flange. The steam is admitted into the stand by a valve opening into the boiler, which valve is controlled by an eccentric wheel above the flange, the whole arrangement being such that if in case of an accident of any kind the stand should become knocked off, the valve would close by the pressure of the steam in the boiler, and, preventing its escape, give the engine crew almost absolute immunity from scalding. Steam is supplied by a pipe running into dome from its interior, and is supplied to the various points by means of small valves, all within the stand itself. The only other openings into the boiler, within the cab, are those made for the water glass and for the gauge cocks; these, however, are more perfectly protected.

Cab.—Made of hard wood, with an extra outside lining of poplar. Front fitted with heavy sheet-iron boiler head plates.

Pilot.—Of oak, 35 inches in height, with up and down slats. Bottom of pilot 3½ inches above top of rail.

Finish.—Cylinders lagged with wood, and cased with sheet iron painted. Head casings of cast iron painted. Steam chest with cast-iron covers, bodies lagged with wood and cased with sheet iron painted. Dome lagged with wood, with sheet-iron casing painted. Boiler lagged with wood and jacketed with Russia iron, secured by Russia-iron bands.

Furniture.—Engine furnished with sand-box, bracket and shelf to receive head-light, bell, whistle, two Richardson safety valves, one set to blow off at 5-inch pressure higher than the other; water glass and gauge cocks, cab lamp, oil cans, tallow pot, etc. Also, a complete set of tools, consisting of two jack-screws, one pinch bar, a complete set of steel wrenches to fit all bolts and nuts on engine, one screw wrench, hard and soft hammers, chisels, poker, scraper, shake bar, slice bar, etc.

Painting.—Engine and tender painted in plain dead black color, with the name of railway painted on collar board of tank, and the number of the engine on a front plate in front of smoke-box; also on each side of sand-box, and in large figures on each side and rear of tank.

Gauges.—All principal parts of engine are fitted to gauges and templates, and are thoroughly interchangeable.

Case Hardening.—All movable bolts and nuts, and all wearing surfaces made of steel or iron are case hardened.

Alloys.—All wearing brasses made of ingot copper and tin are alloyed in the proportion of seven parts of copper to one of tin.

Threads. — All bolt and screw-threads are of the United States standard.

Engine Truck.—Four-wheeled centre bearing; spread of wheels, 5 feet 6 inches; outside to outside of frame-bars, 47 inches; frame-bars held together by a combined cast-iron deck or bolster and centre plate; centre bearing 16 inches diameter; deck well strengthened with ribs, planed, fitted and bolted to upper frame by sixteen 1-inch bolts; deck also provided with two wrought-iron $2\frac{1}{2} \times \frac{3}{4}$ inches safety truss-bars, the ends being bolted to the upper frame-bars for the purpose of supporting deck in case of breakage.

Frame-bars.—Upper frame-bars 94¼ inches long, 4 inches wide and 1½ inches thick; lower frame-bars 85½ inches long, 4 inches wide and ¾ inch thick. Top bars planed on sides and edges to insure straight lines.

Pedestals.—Of cast iron, 14 inches long, 4 inches wide and 1½ inches thick, each being bolted to upper frame-bars by two 1-inch bolts, and to lower frame-bars by one 1-inch bolt, the lower frame-bars having lips forged on to aid in securing pedestals. Sides and faces, also tops and bottoms of pedestals, are planed and spaced 9 inches apart between faces.

Shoes.—Pedestals supplied with cast-iron shoes, planed on all sides, 14 inches long and 5 inches wide on wearing face, and ⅝ inch thick, with flanges ½ inch thick and 1⅝ inches deep.

Cross bars.—Two cross-bars 3 inches wide and ¾ inch thick, bolted to ends of upper frame-bars.

Springs.—Four springs of cast steel, two on each side, with six ½-inch

leaves, $33\frac{3}{4}$ inches long over all, springs bearing on top in a cast-iron saddle; underneath the upper frame-bars, and on each end, in a cast-iron shoe, secured on the equalizing bars.

Equalizing Bars.—Of wrought iron, four in number, two on each side, 4 inches wide and 1 inch thick; the ends of the bars resting on top of boxes.

Boxes.—Of cast iron, with solid brasses $1\frac{1}{2}$ inches thick through crown of brass. Boxes have wearing surface on each side 9 inches long by 5 inches wide. Cellars fitted to boxes by means of a wedge-shaped projection, having a slant of 1 inch in 9 inches, and held in place by a $\frac{3}{4}$-inch key-bolt, passing through corresponding lugs on box and cellar.

Axles.—Of steel, $67\frac{5}{8}$ inches long over all. Wheel seat, $4\frac{3}{4}$ inches in diameter, $7\frac{1}{4}$ inches long; length inside wheel seats, $52\frac{1}{8}$ inches; journals inside bearing, 5 inches in diameter, 9 inches long. Diameter of axle at centre, $4\frac{1}{4}$ inches.

Wheels.—Chilled, double plate, 30 inches in diameter.

Collars.—Axles supplied with cast-iron collars just inside of boxes.

Safety Chains.—Truck supplied with two safety chains, secured to front ends of upper frame-bars.

Wheel Covers.—Of sheet iron, fastened to truck frame.

PROCEEDINGS.

JANUARY 10, 1882:—The 212th meeting was called to order by the Vice-President.

Minutes of last meeting read and approved.

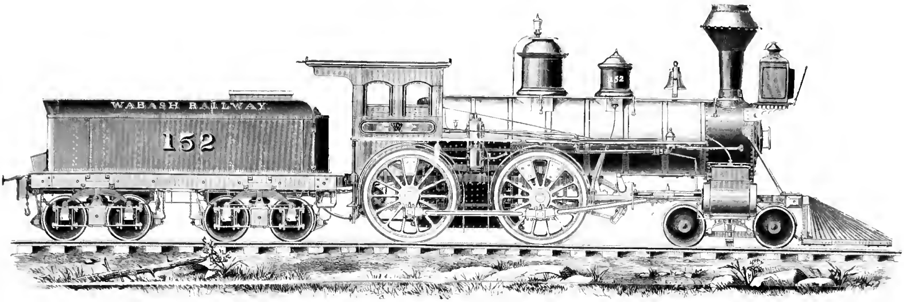
Committee on advertisements for JOURNAL OF ASSOCIATION OF ENGINEERS' SOCIETIES reported and was continued.

Reported from Committee on Annual Meeting that a surplus of \$1.05 was on hand, which was referred to the Treasurer.

Mr. M. L. Holman read a paper by W. P. Gerhard, member of the Club, which paper was in print, and was discussed by Messrs. Moore, Wise, McMath, Holman and Woodward.

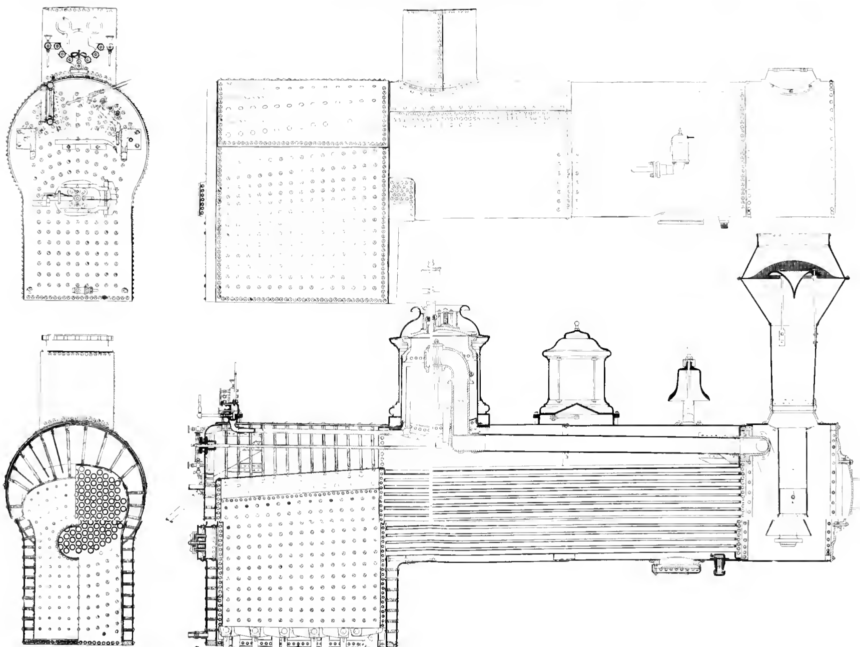
A copy of the history of the St. Louis bridge was exhibited by Prof. Woodward.

[*Adjourned.*]



PASSENGER LOCOMOTIVE No 152 WABASH ST LOUIS & PACIFIC RAILWAY—JACOB JOHANN MASTER MECHANIC

From the National Car Builder January 1882



STRAIGHT-TOP BOILER FOR ENGINE No 152 WABASH ST LOUIS & PACIFIC RAILWAY ILLINOIS DIVISION JACOB JOHANN MASTER MECHANIC

From the National Car Builder January 1882

WESTERN SOCIETY OF ENGINEERS.

ORGANIZED 1869.

TRANSACTIONS.

TRUNK LINE FIELD WORK.

BY SAMUEL McELROY, MEMBER OF THE SOCIETY.

In response to a suggestion from the Committee on Papers, the following copy of general field party instructions has been prepared, with some incidental explanations, as possibly being of some service to younger members of the profession in a class of literature common enough among old "chiefs," but not usually contained in text-books, or analyzed by the integral calculus. And my views as to its possible usefulness have been confirmed in finding how few assistants have been taught the necessity of rudimentary notation in the field, and the advantage of embodying in the corrected field-books all that the finished maps and profiles can show, or is necessary to check or replot them.

Having been called upon quite suddenly, in July last, in consequence of the death of Chief Engineer James E. Abbott, an engineer long identified with the projected trunk railway of the Forty-first parallel, to add to a proposed location of the line through New Jersey and Pennsylvania the responsibility of the entire line from the Mississippi to New York Bay, I have been specially interested in the study of what I find to be the great natural route between the Missouri River and New York.

This route occupies the Gulf slope to the eastern part of Indiana; thence, the Lake slopes to the eastern part of Ohio; it crosses the Allegheny river and its tributaries on the Gulf slope, until it meets the Atlantic slope in Clearfield County, Pennsylvania, which it follows thence eastwardly to New York. Commencing at Council Bluffs, with a level of about 1,036 feet above tide, it crosses the Mississippi, for the present, at Rock Island, about 520 feet above, and thence, via Fort Wayne, 772 feet; Akron, 974; Newcastle, 830, it crosses the Allegheny at 1,000 feet, the Red Bank at 1,130, the mountain summits of Clearfield at about 1,700 feet, the Bald Eagle valley at 800, the Center County summit at 1,400, the Susquehanna at 500, the Schuylkill County summit at 1,235, and the Northampton County summit at 620 feet, a level not quite reached east of the Delaware.

For about 450 consecutive miles then, a line which for over 700 miles will not vary more than 10 miles from the 41st parallel is susceptible of location on ground not lower than about 750 feet above tide, and probably not higher at any point than 1,700 feet. It will bring Chicago within 800 miles, Rock Island within 950 miles, Council Bluffs within 1,230 miles of New York, or 182 less to Chicago than the "Central," 113 less than the "Pennsylvania," and 241 less than the "Baltimore & Ohio." As compared with the tortuous lines, heavy grades, or excessive summits of the four trunk lines, the problem of such a result in location may well absorb an engineer's interest, and prompt the most diligent study of its conditions and solutions.

The general instructions embody only certain general rules of field practice. Local cases, of course, require local adaptations.

In the Alleghanies and through most of the Pennsylvania line, after a careful study of the water-courses and a collation of the profiles of the railways and canals in this section of the State, a general line for survey was projected, guided also by previous examinations, and in each county this line in detail has been given the assistants in charge. In this way, while considerable latitude is left to them, the line is substantially outlined, and its results fixed in advance at various important stations, so that the main office has a constant check on the field work.

In the eastern part of Pennsylvania some such prominent guides in location were available; but not many north of the Lehigh River. It had been assumed that the Wind Gap of the Blue Mountains was the most direct line from Belvidere, on the Delaware, to the Upper Lehigh; but the levels of this gorge and the railway which approaches, but could not use it, from Bethlehem, taken in connection with some flying examinations, made it probable that an equally direct and much more favorable line could be found along the Lehigh slope, and this assumption has been fully verified by a survey now complete to the Lehigh Gap, with a summit more than 300 feet below the Wind Gap, and a highly favorable line as to distance and tangents.

To put the rule of such a problem in location in a few words is to re-assert the old engineering maxim, "First find out what others know, and add all you can to their experience." An engineer who prides himself on "getting the country for himself" might as well keep out of the Alleghanies.

Some explanatory notes have been added to the following instructions.

GENERAL FIELD PARTY INSTRUCTIONS.

OFFICE OF CHIEF ENGINEER,
CONTINENTAL RAILWAY CO.,
Sept. 19, 1881.

Transit with level books must show daily journal as to time of survey; State, county, town and section (*a*); weather; character of ground, rock, clay, gravel, loam, etc.; cultivation, woods, brush, etc.; swamps, creeks, rivers and soundings (*b*); notes of extreme flood-levels and dates on streams, kind of navigation, exposure of bridges to ice, timber, fire, etc. (*c*); farm lines, roads, railways, canals, village or city streets, adjoining structures or places, courses of lines crossed, boundaries and owners;

neighboring tie-timber, ballast, quarries, mines, and other notes affecting facilities and cost of construction, right of way, or change of line.

Transit notes to be kept from bottom to top of right-hand page: right or left deflections plainly distinguished: angles and courses noted together ; topography, lines, etc., sketched: notes allotted to leveler distinctly defined. On tangents, the forward station to be a mean between the first reverse and a reverse of the instrument from the back sight (*e*).

Level to be kept in adjustment, bubble level on sights, stations equidistant where practicable, notes kept by "height of instrument," check-book kept by rodman, benches carefully selected, located and sketched, guide benches found and used, level work kept well up to transit, and such soundings, locations and other notes recorded as the assistant in charge directs (*f*).

Daily field work to be checked, corrected and inked up nightly, and maps and profile plotted up, horizontal scale 400 feet, vertical 30 feet per inch (or scale of profile paper) (*g*).

The theory of this location is to secure a direct trunk line, balancing future cost of operation against that of construction, avoiding the tortuous lines of deep valleys and the summit elevations of hills, to secure nearly uniform levels. In rough ground the assistant in charge will therefore make flying triangulations and levels, and cross-section spur lines from his preliminary line, for guidance in location, on the route substantially indicated, and keep himself well informed as to the country ahead of his party (*h*).

Parties to consist of assistant in charge, transitman, leveler, rodman, back chainman and such axemen and others as the local work may require and no more, with a paymaster to pay accounts as approved by the assistant, and provide lodgings, meals and transportation. Assistants of rodman rank and upward to be paid by the month, below this, by the day, except that time lost by voluntary neglect is to be deducted: to provide their own instruments and drawing tools.

The assistant in charge to be responsible for the promptness, industry, politeness and sobriety of his party, with authority to suspend or discharge for cause, to replace, and to hire and discharge subordinates. Rates of pay to be approved by the President and Chief Engineer.

Weekly reports to be made of work done, information obtained and work ahead, suggestions as to line, party, etc.; section maps, profiles and transfer field books to be sent in to this office, as completed. Three days notice of post-office or telegraph station, ahead, to be given.

SAMUEL MC. ELROY, Chief Engineer.

NOTES.

(*a*.) A neglect of dates and locality in field books is entirely too common, and leads to confusion. It would be an advantage to have them practical daily journals of the party, with matters of interest to the work fully noted, and this can be concisely done without occupying much space or time.

(*b*.) The swamp and stream crossings may bear so material an influence on the location of a line that their character should be carefully noted

as they are met. The details may properly be assigned to the level party.

(*c.*) The relative exposure of streams to freshets, and their consequences to culverts, bridges, approaches and foundations are also important features in construction, and require careful study. Very frequently, in wooded valleys, the freshet drift will indicate extreme levels by its deposits; but in all cases the best local authority should be consulted.

(*d.*) All angles on the main line should be read from the vernier, without trusting the needle; but the courses given by the needle are valuable as checks on the readings, a mistake of five or ten degrees being easily detected in this way, and the comparison should be made before the station is left.

(*e.*) In field work the apparently simple processes of measuring and of running straight lines correctly really require a high degree of skill. On preliminary work close measurements need not be made, as they properly belong to final location: but carelessness in prolonging tangents should be avoided as much as possible. A transit should be kept in good adjustment, and if well made will not require it as often as a level does; but no transit will reverse accurately, as usually handled. It should be set up firmly with head level and equable pressure on the legs; avoid jamming a leg, leveling screw or clamp: an instrument works best delicately handled. By reversing on the Y axis a stake can be set on the forward station, and should have a head about 2 inches wide; let the flagman mark it by this sight: then reverse the whole instrument and from the back sight, by Y reverse, give him another point; on a thousand feet sight or so, both points should come on the same stake, and the nail driven between them corrects the error of collimation, and it is thus possible to run long and accurate tangents with an ordinary railroad transit. On the Kings County street survey the most important monument base lines were put in in this way, and with flagmen properly drilled very little time is used.

(*f.*) One important secret in keeping a level in adjustment and in accurate work is delicate handling. The plates and legs must be kept from unequal strains by the manner of setting and leveling up. Where stakes are some distance apart the leveler should pace equal stations if the ground permits; if not, special care is needed to have the bubble level in sighting, which a slight pressure of the finger on the plate will secure if needed.

The old Erie Canal rule of giving the rodman a book to keep is of great service, especially where sound and hearing are impeded; 11 and 7 are numbers easily confounded at the instrument, and with two sets of notes, checked at lunch or night, an error or a doubt can be settled at once, or the station indicated for correction by releveling.

Rodmen should be educated men, candidates for promotion, and habituated as occasion serves to the use of the level, as levellers should be to that of the transit; in this way an assistant can avoid embarassment by temporary causes. Forward flagmen should also be educated candidates for promotion and drilled accordingly. One of the most dangerous members of a field party is a full-fledged graduate with an axe in his

hand: but it is his own foot or leg which usually suffers. If our technical schools would only preach to their graduates the common sense of beginning field work as subordinates and earning rank by actual service, it would much promote their substantial success: and the wise student will be content to build on the valuable foundation of theory, the practical construction of patient, faithful and modest daily growth.

(*g.*) The importance of nightly working up field notes cannot be over-estimated. Pencil notes are easily blurred or obliterated: notes trusted to memory are soon forgotten; those open to question should be promptly settled and recorded. It is just as easy to break a party into careful habits as to let them neglect duty for waste evening time.

The importance of making a full and clean collation and copy of the original notes in duplicate is also self-evident. A field book lost cannot be replaced: and in a fair copy the notes can be put in much better and more regular form for use as well as for preservation. Questions of great consequence to the interests of a company have at times depended solely on the integrity of the field books.

(*h.*) The value of a base line survey in preliminary study of a difficult country, with spur lines at proper points, or cross-sections to cover alternate lines, and the rapidity, economy, and advantage of flying triangulations, cannot be over-estimated. This furnishes the data for "office" location, a far superior method than "field" location where the notes are properly taken. Trial lines may be repeated in considerable number without securing the best final location, or furnishing sufficient data for it. I have known an eminent, but not really experienced, engineer to spent the best part of a year in running trial lines to improve on a location put at his service before he began, and make no material change in it at last.

In valuable sections, where right of way is expensive, and it is not advisable to notify the owners on the line of its exact proposed location, I have, on various occasions, made a base line survey, or road and farm survey, and an office location, so as to secure right of way before the stakes were put in.

(*i.*) Stations should be 100 feet apart, numbered 1, 2, 3, etc.: stakes 300 feet apart, left in plain sight, blazed, and numbered with red chalk: transit plugs driven flush with the ground, with a "finder" beside them, and located from convenient objects, where it can be done. Sections to be divided into about ten-mile lengths, or limited, near this distance, by a town or county line, stream, road, or other established and convenient boundary. Station numbers confined to sections, and sections to States.

PROCEEDINGS.

JANUARY 7, 1882:—The 139th regular meeting was held at 7 P. M.

No quorum was present and no business was transacted.

L. P. MOREHOUSE, Secretary.

FEBRUARY 7, 1882:—The 140th regular meeting was held at 4 P. M., Vice-President Creiger in the Chair.

After the reading of the minutes of the two preceding meetings, which were approved, the Chair, in a brief eulogy, announced the death of Mr. Moses Lane lately one of the Vice-Presidents of the Society and one of its oldest members.

Mr. Chesbrough moved that a committee of three be appointed to prepare a memorial upon the death of Mr. Lane. This was adopted by a rising vote, and the Chair appointed Messrs. Chesbrough, MacRitchie and Nichol as such committee.

Applications from the following named gentlemen for membership were received: William Henry Lotz, mechanical engineer, 93 Fifth avenue, Chicago: Henry C. Draper, civil engineer, Chicago & Alton Railroad, Chicago; George C. Smith, civil engineer, Chicago, Burlington & Quincy Railroad, Chicago; Francis D. H. Lawlor (associate), Engineer's department, Chicago, Burlington & Quincy Railroad, Chicago.

Upon ballot, Mr. Robert Alexander Brown, assistant engineer in charge of Illinois River improvement, proposed at the 137th meeting, was elected a member.

Mr. Chesbrough, the retiring President, delivered an address, which is printed elsewhere as a part of the Transactions of the Society.

The Secretary read a letter from the recently elected President, Mr. Willard S. Pope, accepting the position.

Col. FitzSimons made a verbal report as Treasurer, ratifying the annual report of the Secretary as it related to the finances of the Society.

[*Adjourned.*] L. P. MOREHOUSE.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

ORGANIZED 1880.

TRANSACTIONS.

SUGGESTIONS FOR A FAVORABLE DISPOSITION OF MATERIAL IN BRIDGES.

By G. Lindenthal, Member of the Club.

[Read December 4, 1880.]

For the calculation of a bridge the loads are assumed static, and for bridge parts taking their strains suddenly either a certain percentage for impact is added, or lower unit strains are used. No correct data from experiments are known for estimating the strains under impact, and theory does not help us any on this question. I refer particularly to railroad bridges. The tendency is toward heavier engines, heavier cars, longer trains and faster speeds. Years ago, when a 36-ton engine was considered a heavy one, when a car load of 12 tons was thought to be extreme, and when such trains in approaching a longer span bridge were cautiously slackened up, it was thought that one ton per foot of track for live load was quite a liberal allowance in building a railroad bridge. Iron bridge-engineering in its infancy was also not free from sentimentality. Builders thought it to be their first and principal business to invent a new bridge-type. To certain inclinations of posts or rods was ascribed an extraordinary value, worth much money in the form of royalties. The faith in iron was great: elastic limit was not mentioned, but an ultimate strength of 60–70,000 pounds per square inch freely asked for in specifications.

Now we have to deal with different conditions. We have engines of 40 to 56 tons without the tender; we have cars carrying 20 tons and more, and such trains when behind time or on down grades will rattle along at 25 to 30 miles an hour, slackening for no bridge. We have express trains of heavy mail, passenger and sleeping cars, sweeping along at 50 to 60 miles an hour. They strike a bridge, and anybody standing on the same will have to hold on not to be shaken off. The lateral vibration of the bridge can in many instances be more distinctly felt than the vertical vibrations. How shall we provide for these vibratory strains, the dynamic effects of the live load? They are not calculable, at least, not with certainty or precision, though they can be explained. Take a

belated mail train at 50 miles an hour, or at 73 feet per second. To load a 150-ft. span it will take about two seconds. Is it probable that the stresses in the bridge members occur with such nicety as we get them by assuming the live load as static? Do the bridge members have time enough to do their work as promptly and neatly as we calculated it, or can the strains travel fast enough to just produce that strain which we obtained by assuming the load stationary or slowly rolling? Whoever has ridden on a locomotive knows its staggering motion at great speed, produced by its top-heaviness and other causes. The driving wheels have play between the rails for their flanges, and the joggling motion of the same tends to overturn the rails and twist even the solid road-bed out of shape. It requires a permanent force of men to maintain a well-surfaced and well-lined track. What is bad for the solid track is worse yet for a bridge. The engineer should in some manner provide against those violent vibratory strains by using good judgment in the selection of a truss-type and in the arrangement of details in the construction.

There is an accepted standard form of truss for railroad bridges of ordinary spans. This is the parallel-chord truss; for a through bridge with inclined end posts, for a deck bridge with vertical end posts. It is the easiest to manufacture, to transport and to erect; it affords an effective lateral and diagonal bracing. In the arrangement of web members there are a number of variations.

By having short panels and the double quadrangular type in moderate spans, the web members become slender and thin. The web strains are distributed and have to travel through a greater number of slender parts, which are brought into vibration quite easily; the floor beams and stringers for short panels are light, and also vibrate easily. A greater proportion of material, which should be in the floor system, is needed for the greater number of web members; for a through bridge this is particularly disadvantageous, becauses it raises the centre of gravity of the structure and decreases its stability. It is true that no part in a bridge takes its full strain from the live load instantaneously, but gradually increasing from zero up to a maximum; however, this increase takes place in a very short time. It can be said to take the form of a "shock." Take a bridge, 150 feet long, 12 panels, 12½ feet each, and a train at 50 miles an hour; each track-stringer will be loaded from zero up to maximum in about ⅙ second. From the stringer the "shock" goes into the floor beam, and from the floor beam the trusses receive each 6 shocks per second from each pair of wheels passing over the bridge; and for wheels averaging 10 feet apart there will be 44 shocks per second to each truss.

To estimate the effect of these hammerings we should know something about the *rapidity* with which a shock can be safely transmitted in iron, steel, or other material. The nature of the bridge strain is somewhere between the instantaneous strain produced by a dropping weight and the slowly increasing strain of the testing machine, nearer to the former than to the latter. Theoretical speculation can go rampant on this question, but experimental tests alone can give reliable data. It is obvious, that if the panels in the above instance were twice as long (25 feet) the number of shocks would be *half as many* and *half as sudden*, though the trans-

mitted loads would be twice as great: with the same unit strains and the same percentage for impact in both cases (as is often done), the connections for the longer panels will be safer. It is also clear the more material there is in the floor (within economical limits) the greater the bulk into which the shock will be distributed, and the more elastic the material of the floor the more it will absorb of the shock and the less impinge on the connections.

The conclusions are, then:

1.—A design with long panels is preferable to one with short panels.

2.—Solid plate girders are preferable to lattice girders for short spans and for floor girders.

3.—Wooden stringers would be advantageous on account of their bulk and elasticity: but as they are a source of danger from fire and rottenness, stout ties, closely spaced and resting on iron stringers, *further apart* than the rails will help to absorb the shocks from live load.

In a bridge with long panels the strains and metal are massed into fewer parts, which become bulky and stout and will not vibrate easily and violently. Floor beams and stringers will need to be deep and heavy for long panels; there will be excess of material at the end of flanges and middle of web, but it will be where it does the most good. The stability of the bridge will be greater.

From observation I believe that the lateral bracing in short spans is more strained from the lateral vibration of the bridge under fast moving trains than it ever is from the wind, for which it is calculated. A liberal allowance in proportioning it will benefit the bridge immensely.

Wherever practicable attach the lateral bracing directly to the chords. The width of the bridge is also to be taken into consideration and to be proportioned to its length. If a single-track bridge, it should not be less than one-twelfth of its length: if it is less, then trains should slacken their speed in passing over such bridge.

For double-track bridges, use only two trusses for through bridges: they are more economical than any other arrangement: besides, their heavy floor and greater width make them much stiffer than a single-track bridge. The floor-girders and trusses are not as frequently strained up to the calculated maximum, which occurs only when trains meet on the bridge.

Another important part of a through bridge is rigid and strong portals, to keep the trusses plumb. I have noticed several bridges in which the portals were of slender make and shaky from the vibratory action of the end posts. These were out of plumb. In consequence, the diagonal ties had become unequally strained and the deterioration of the bridge in this way had begun.

The triangular or Warren type has no adjustable web members, and for long panels the least number of them of any type. An objectionable feature of this type was thought to be the alternate strains in some web members. It is not much of an objection now, when workmanship can be had more perfect than years ago.

For strains up to 100 feet for single track, riveted girders will give the most rigid arrangement. The theoretical excess of metal of a riveted bridge is a benefit rather than otherwise, because it helps to make it

rigid. The chords are unbroken, their solid riveted sections are not so liable to be in unequal tension or compression, and if the connections have been planned with care they remain rigid and undisturbed. I wish not to be understood to advocate them for longer spans when they become objectionable for other reasons.

I believe engineers are looking in a wrong direction by trying to invent new designs to build a bridge of ordinary length with the least amount of material. They, of all, should know that something cannot be got out of nothing. Iron bridges are light; they should not be too light—they should not be too heavy. Railroad companies cannot afford to pay for useless or superfluous material in a bridge. Again, some allowance should be made for possible accidents.

It is not desirable that a derailed car, costing $600, should ruin a bridge costing $10,000. Brakes should not be applied on a bridge or trestle, except in case of danger: the short hard shocks are quite severe on bridges and trestles.

We cannot build a bridge so that trains may run into one another on the bridge as well as they can outside of it; but we can build a bridge so that derailed cars, or even locomotive, can pass over it on the ties, without striking the trusses; but then you should not build a truss with posts having only half a pinhole for bearing on the pin, or with the rail ties a foot or more apart and with an insufficient guard rail. Such a half-hole post on one of these fancy bridges knocked out of position by a derailed car will surely bring the bridge down, and possibly bring down with it the railroad company.

At the ends of a bridge should be improved rail guards, that will lift the derailed car in a train on the track again. Some are in use, which have actually saved bridges from being wrecked by derailed cars.

There is a large field yet open for improvement in bridge-engineering, by devising means to get the best possible workmanship, good material, and disposing it to best advantage for all possible conditions. An iron bridge is a permanent structure; for permanent structures foresight should be used for future needs and developments.

In proportioning the sections for members go on the principle that it is better to use one stout rope than a dozen thin ones, because it is next to impossible to strain them all alike.

Better allow a lower unit strain and use stout sections than to use a larger number of smaller bars, which may get bent and bruised during transportation, and when put in the bridge will take only indifferent strains. Railroad and highway bridges can be found all over the country with bottom chords out of order; of a half a dozen bars on the same pin a few *may* do the work, the rest will be found loose.

In proportioning a compression member, give it an open section that can be painted inside and outside. It is all very well to point to nature, that it observes the nicest mechanical laws in building a straw-stem or a goose-quill and that the tube form is the most economical. It is more important that the metal should be painted on all sides to protect it from rust, and that the post should have a form to which attachments can easily be made. As faulty as it is to use a closed section with metal $\frac{3}{16}$ inch thick, because theory allows it, just as faulty is it to build a long com-

pression member, for instance, of I beams and two flange plates, where most of the metal is massed near the centre of gravity instead of away from it, and justify this by Gordon's formula.

When a larger bridge is to be built, then it furnishes a problem by itself. Locality in or out of a city, the use of steel and other factors have to be studied. I am not prepared to say that for longer spans the parallel chord truss is also the best. When a bridge span has a width equal to $\frac{1}{24}$ of its length and a truss height $2\frac{1}{4}$ times that of the width and at a high elevation exposed to violent winds, its stability is not very great, and trains have to creep over it cautiously.

I believe that other truss types would answer better the purpose and would also be more economical.

STORMS OF THE AMERICAN CONTINENT.

BY GUSTAVUS A. HYDE, MEMBER OF THE CLUB.

[Read December 4, 1880.]

It has been but a little over fifty years since the people of this country were first made acquainted with some of the characteristics of the storms that traverse the American Continent. Professor W. P. Redfield first advanced the idea that the motion of the air around a storm centre was nearly circular, and this intelligence was followed by the announcement of Professor J. P. Espy that the tendency of the air in a storm was toward its centre.

In 1842 Professor Espy, by authority of the Surgeon-General of the United States Army, inaugurated a systematic plan of investigating these great storms, by issuing a circular inviting all persons interested to volunteer their services to engage in taking daily meteorological observations in the United States, and also throughout the world, on land and sea.

A favorable response was received from more than 50 persons who had barometers, and from more than 60 who had no barometers, and observations and records were soon after commenced.

Such was the beginning of what is now known as the Signal Service Weather Department of the United States.

This invaluable scientific investigation continued under the charge of Professor Espy until his death, when it was given into the care and control of Professor James Henry, Secretary of the Smithsonian Institution at Washington, D. C., under whose management it was successfully prosecuted until a weather bureau was formed about 12 years ago, under the War Department, for its special care and advancement.

The Weather Bureau receives daily by telegraph, observations taken at 143 Signal Service stations and 15 Canadian stations, and monthly registers from 204 volunteer observers, 41 monthly registers from United States army post surgeons, and a variety of other information from other sources. Forecasts of the weather through this department have been remarkably accurate, about 90 per cent. of the predictions being verified, and the information thus far obtained has confirmed the opinions advanced by Professor Redfield and Professor Espy. Other characteristics

have been discovered, and the fact clearly demonstrated that the service is of incalculable benefit to the commerce of our country, on lake and ocean, saving hundreds of lives and millions of property annually.

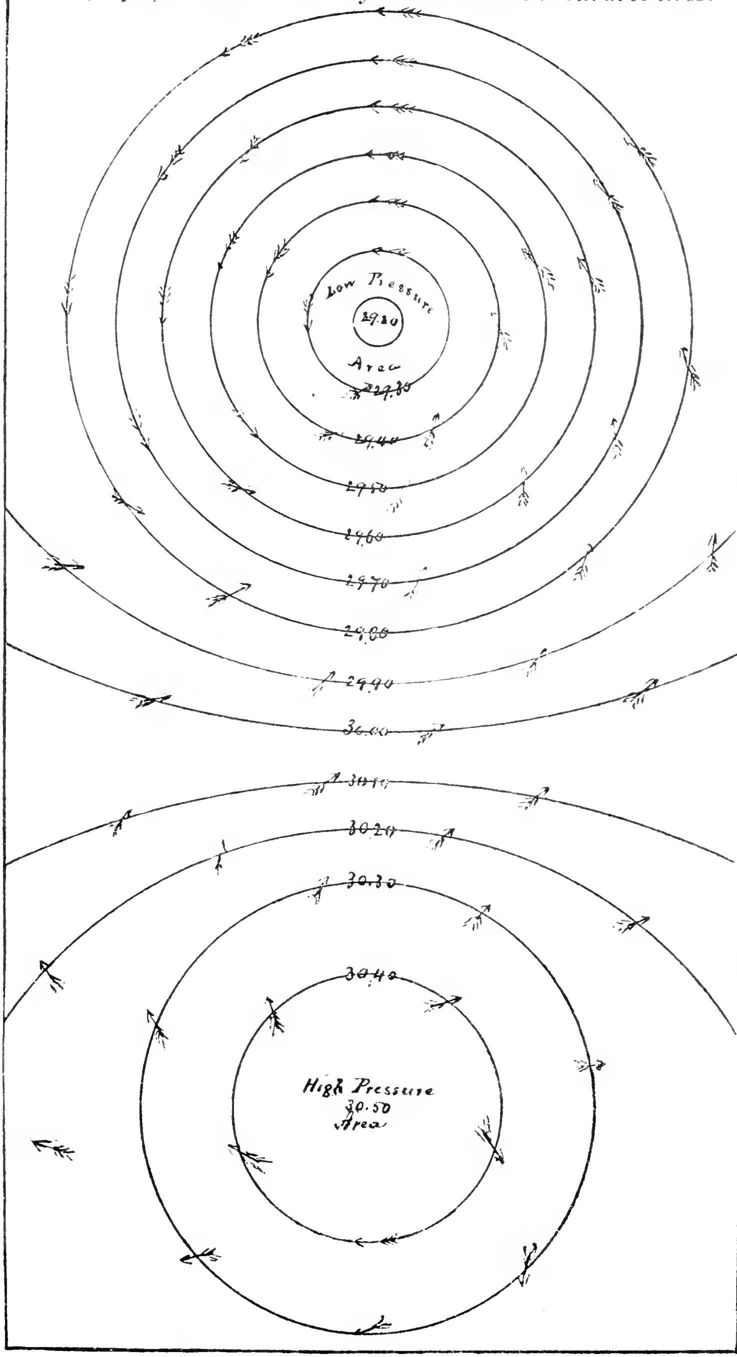
The storms under consideration are extensive atmospheric disturbances, or whirlwinds of immense proportions. Their origin, says Professor Espy, may be stated thus: If the air of any locality acquires a higher temperature, or a higher dew-point, than that of surrounding regions, it is specifically lighter, and will ascend; in ascending, it comes under less pressure and expands; in expanding from diminished pressure, it cools in its ascent, and its vapor is condensed into cloud. In condensing its vapor into water or cloud it will evolve its latent caloric: this will prevent the air from cooling so fast in its further ascent. The current of air, however, will continue to ascend and spread out in all directions above, overlapping the air in all the surrounding regions in the vicinity of the storm, and thus, by increasing the weight of the air around, cause the barometer to *rise* on the outside of the storm, while the less ponderable matter near the centre of the upmoving column would cause the barometer to *fall*. The pressure being below mean near the centre, and above mean near the outside of the storm, the wind will blow on all sides from without, inwards toward the centre. The air thus drawn or attracted to the storm-centre comes laden with vapor, and as it ascends becomes condensed by the cooler upper atmosphere, evolves its latent caloric and augments the ascending column of air, causing high winds, gales, tornadoes, etc. The air that is drawn to the storm centre does not move on a line directly toward the centre, but moves around the centre in a direction the reverse of the movement of the hands of a watch, and in a line between 45° from radius and the line of the circumference of a circle formed by the line of equal pressure, as shown on diagrams *A* and *C*. This causes the winds on the northerly side of the storm centre to blow from an easterly direction; on the westerly side from a northerly direction; on the southerly side from a westerly direction, and on the easterly side from a southerly direction. The rotary movement of the wind around the storm centre is not effected by the direction or velocity of the body of the storm in its passage over the surface of the earth.

Besides the high pressure which occurs at the outer limit of the storm and caused by the low pressure at its centre, there are high-pressure areas which traverse the country, whose characteristics are the reverse of the low-pressure areas. The rotary motion of the air around a high-pressure area is in the direction of the movement of the hands of a watch, downward from above and outward from the centre, in a line between the circumference of a circle formed by the line of equal pressure and 45° from tangent to said circle, as shown on diagrams *A* and *B*.

The high-pressure areas that move over our continent are the cause of the cold waves that visit us. Many of the high-pressure areas are probably caused by the adjacent low-pressure areas or storms, but I would suggest that some are caused by remote atmospheric disturbances moving the enormous high-pressure cold area of the north-pole region from its ordinary position, forcing it down on to our part of the earth's surface and relieving some other portion.

The nuclei or centers of the low-pressure areas or storms are of varied

(A) Illustration of lines of equal pressure and direction of winds accompanying Low Pressure and High Pressure Areas or Storm Centres.

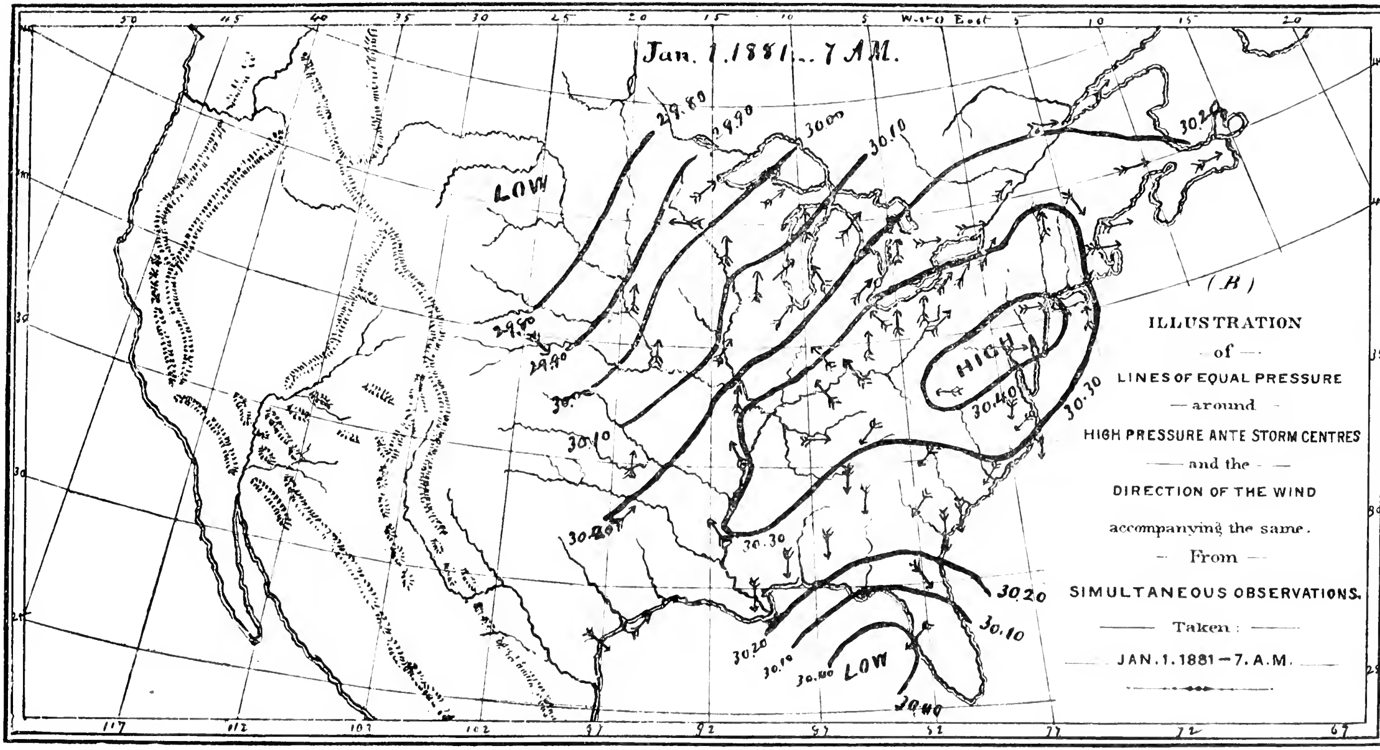


diameters, probably from 5 to 50 miles. The portion of the storm area that has the least pressure is usually round or nearly so. The portions that have higher pressure than the center are sometimes round, but more frequently elongated. The elongation is sometimes in the direction of the route of the storm, as illustrated in storm shown in diagram (*c*), but more frequently it is transverse. The form of the storm sometimes changes from round to elongated and also the reverse during its movement. The outer diameter or limit of influence varies from 1,000 to 2,500 miles. Very many of the storms that traverse our country originate in the region of the Rocky Mountains: some come from the Pacific Ocean, and a few from the Atlantic Ocean east of the West India Islands and others from the Gulf of Mexico.

The storm having formed does not long remain at rest, but moves on its course over land and sea at rates varying from 5 to 60 miles per hour, but ordinarily at the rate of 30 miles an hour. The routes traversed by storms are quite diverse, illustrated by the following examples: Storms formed in Dakota and territory north have taken an eastward course through Canada to the Atlantic: others forming in the same region have moved southeasterly to near St. Louis, then diverged to the northward for a few hundred miles and then moved eastward near the lakes and the St. Lawrence River to the Atlantic Ocean. Occasionally a storm has passed from Dakota Territory in a southerly direction into the Atlantic Ocean. Some storms come from the Pacific Ocean, entering our country in Oregon, pass down the west side of the Rocky Mountains into Texas, then move eastward through the Gulf and Atlantic States and into the Atlantic Ocean. Sometimes, after following the same course to the vicinity of New Orleans the storms pass northward near the Mississippi River, and then follow the lakes and St. Lawrence River to the Atlantic Ocean. Once or twice during a year, a storm forming in the Atlantic Ocean, eastward of the West India Islands, moves westward over those islands, then passes northward and follows the Atlantic coast or Coast States and enters the Atlantic Ocean near Newfoundland: or else passes westward of the West India Islands across the Gulf of Mexico to the mainland and then turns and follows the coast or Coast States as before mentioned. Whatever may be the place of origin or point of entering our country the routes of these storms are so directed that in the majority of cases they leave our continent in the region of Newfoundland and continue eastward near the Gulf Stream across the Atlantic Ocean.

Thence some of the storms pass north of the Continent of Europe, some pass southward as far as the Mediterranean Sea and others cross the continent by various routes and are expended in Asia or in the Pacific Ocean. Occasionally a storm makes the entire circuit of the earth, being expended near the point of development, and requiring about thirty days for its passage. The storms that form south of the equator revolve in a reverse direction from those formed north of the equator, and storms formed on either side of the equator never cross it.

The approach of a storm centre is indicated to a local observer by the fall of the barometer below its normal height and its locality by the direction of the wind. If it is west of the observer the wind will blow



Jan. 1.1881... 7 A.M.
(B)
ILLUSTRATION
of
LINES OF EQUAL PRESSURE
around
HIGH PRESSURE ANTE STORM CENTRES
and the
DIRECTION OF THE WIND
accompanying the same.
From
SIMULTANEOUS OBSERVATIONS.
Taken :
JAN. 1. 1881 — 7. A. M.
LOW
HIGH
LOW
29.80
29.90
30.00
30.10
30.20
30.30
30.40

from a southerly direction, if north of the observer the wind will blow from a westerly direction, and if south of the observer the wind will blow from an easterly direction, etc. As long as the barometer continues to fall the storm centre is approaching the observer, and whenever the barometer ceases to fall the storm centre is either passing over or has ceased to approach the observer, but may be moving on a line equidistant from the observer. Whenever the barometer is rising the storm centre is moving from the observer. Whenever the barometer falls slowly the storm centre is approaching the observer slowly, if moving directly towards him, or else it may be moving rapidly on a line not towards the observer. Whenever the barometer falls rapidly the storm centre is approaching rapidly. Whenever the barometer is rising very much above normal height, a high-pressure area is approaching. This usually brings clear weather alone, but sometimes rain or snow, followed by clear weather. The precipitation of rain or snow is sometimes made on both the approach and retreat of a low-pressure storm centre; sometimes on the retreat and not on the approach, and sometimes there is no precipitation during portions of its advancement.

During the passage of the centre of a low or high-pressure area over any locality there will be a calm, and the wind, previous and subsequent, will blow from nearly opposite directions.

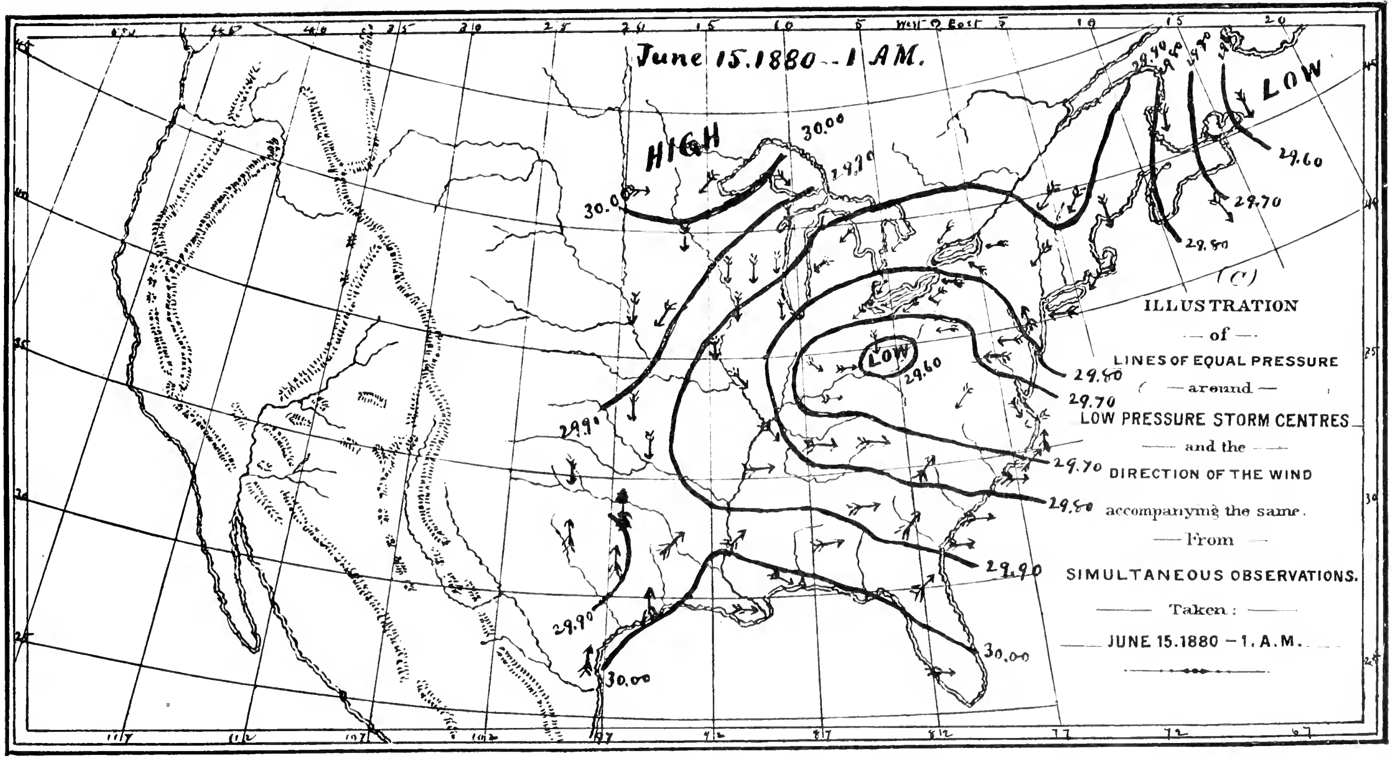
The general characteristics of all storms are the same, being governed by the same laws, which are well understood by meteorologists, as demonstrated by the forecasts of the weather made by the signal officer; but no law has as yet been discovered to determine beforehand when a storm will be formed or what course it will take in its route over the surface of the earth. There are many weather-wise persons who undertake to predict the weather for weeks and months in advance. They say that on this day or on some other day there will be a storm. By reference to the charts of storms published by the Weather Bureau, it is clearly shown that there are a multitude of storms in some portions of the earth at all times. From ten to twenty storms originate or come on to and pass over our country every month of the year. Sometimes, and not unfrequently, there are three storms on this continent at the same time.

It is equally impossible to tell beforehand whether we will and where we will have cold or hot, or wet or dry weather. Extremes do not always follow each other. What has been may not soon occur again.

If the present system of international meteorological observations are continued, atmospheric phenomena now unknown will probably be brought to light, and with the aid of daily telegraphic reports of simultaneous observations throughout the world, nearly accurate forecasts of the weather may be made for a longer time than are made at present.

DISCUSSION.

Considerable discussion followed, during which Mr. Hyde stated that except about once, sometimes twice a year, almost all storms proceed from the west or southwest across the country to the eastward, sometimes taking a circuitous route, but nearly always passing in the vicinity of the Gulf of St. Lawrence. The destructive storm which passed along the coast of the Middle and Southern States, doing such damage at Philadelphia and other places about two years ago, was one of the notable excep-


June 15.1880 - 1 AM.
HIGH
LOW
LOW
30.00
29.60
29.70
29.80
29.90
30.00
(C)
ILLUSTRATION
— of —
LINES OF EQUAL PRESSURE
— around —
LOW PRESSURE STORM CENTRES
— and the —
DIRECTION OF THE WIND
accompanying the same.
— From —
SIMULTANEOUS OBSERVATIONS.
— Taken: —
JUNE 15.1880 – 1. A.M.

tions to the general course of storms. He said he had no particular theory upon which to account for this direction taken by storms, but had thought perhaps it might be due to the moisture and attraction of the Gulf Stream. By far the larger portion of the storms originate in or come by way of the west and southwest.

PROCEEDINGS.

JANUARY 10, 1882:—Regular meeting. Vice-President Col. J. M. Wilson in the chair. Minutes of last meeting read and approved. The name of W. H. Phillips, recommended by Messrs. Schwägerl and Reed, and the name of Henry Wood, recommended by Messrs. Cully and Mordecai, were presented as candidates for active membership. On motion, the Secretary was requested to cast favorable ballots for the election of Messrs. J. H. Eidelman, J. T. Watterson and F. L. Krouse.

The Committee on Library and Publication reported on the matter referred to it at last meeting relative to the number of copies to be given to the authors of papers published. Report received.

Mr. Mordecai, of the Committee, submitted the following resolution, which was adopted:

Resolved, That the members of the Board of Managers, on joint publication, be requested to have a rule adopted by the Board providing that the writer of any article published in the proceedings be furnished any number of copies of the article not exceeding twenty-five, and in addition any number of copies of the JOURNAL containing the article not exceeding five, providing he expresses his wishes when handing over the paper for publication.

The same committee reported adversely upon the proposition to procure correct stenographic or long-hand reports of the discussions upon papers and topic presented to the Club, but presented as a substitute the following resolution:

Resolved, That any member taking part in the discussions of the Club be requested to hand to the Secretary either a full report of his part of the discussion or a synopsis of his statements and arguments. Resolution adopted.

The following expressions of respect to the memory of a deceased engineer (Mr. Theodore R. Scowden, who died at Jacksonville, Fla., December 31, 1881) were submitted by Vice-President Wilson, and on motion of Mr. Baker were recognized as the expression of the Club, and were ordered made a part of the Record:

"The Chair begs to invite the attention of the Club to the fact that one of the ablest members of our profession has during the past week been carried to his last home.

"Although not a member of our Club, Mr. Scowden was a resident of our city, was closely identified with some of the earliest and most important engineering works undertaken in Cleveland, and by his ability, energy and integrity placed himself in the front rank of the leading engineers of the country.

"It seems meet and proper that we should notice the death of so eminent an engineer, lately residing among us, and that we should express our sincere regret at his loss, our sympathy for his afflicted relatives, and our appreciation of his distinguished services as a member of our profession."

Prof. Wood then gave the Club an extended reply to the question of Dr. Brown, submitted to him at the last meeting, "What is the chemically scientific definition of crystallization?" illustrating his remarks by specimens of crystals of alum, mica and other substances, after which the Professor gave the Club an interesting paper on the general subject of "Crystallization," presenting a large number of specimens of steel and iron in various conditions, burnt and crystallized.

A recess was then taken to enable the members to examine the large number of specimens of crystallized and fibrous iron which the members had kindly furnished; after which a general discussion followed on crystallization of iron, which was participated in by Messrs. Bidwell, Halloway, Hyde, Professors Arey, Wood and others.

On motion, the Chairman was authorized to appoint a committee of three to draw up a petition to present to Congress, requesting further appropriations to continue the tests of iron, etc., by the General Government, and to invite the co-operation of engineering and other similar organizations throughout the country.

The thanks of the Club were extended to Prof. Wood for his paper, after which, upon motion, the Club adjourned to meet on the second Tuesday evening in February.

C. H. BURGESS, Secretary.

BOSTON SOCIETY OF CIVIL ENGINEERS.

ORGANIZED 1848.

TRANSACTIONS.

This Society is not responsible as a body for the statements and opinions advanced in any of its publications.

THE STABILITY OF CERTAIN CONICAL ROOFS.

BY EDWARD S. PHILBRICK, MEMBER OF THE SOCIETY.

[Read February 15, 1882.]

It has been customary in this country—at least in its northern portion—to cover gas holders with walls and roofs, though the custom is now yielding to the practice of building open holders, as has been generally done in milder climates.

The wants of the gas companies in providing storage for their product have been constantly increasing with the growth of population and the increased demand for the gas. The result has been the construction of some holders of late which are so broad as to make it too costly to roof them, *e. g.*, the holder of the Boston Gas Light Co., on the South Bay, is 200 feet diameter. Still we have many such structures in this vicinity with roofs of over 100 feet diameter. They are sometimes of the dome form, but oftener conical. A recent experience with a conical roof of about 115 feet diameter has shown that the methods which have often been adopted in building such structures are not likely to prove satisfactory.

Now, although gas holders of such a size may not hereafter be constructed with roofs, still the conical form possesses some advantages for the roofing not only of gas holders, but of other large circular buildings, so that it may be of interest to look into the behavior of one of those which was constructed over twenty years since. This instance is by no means an uncommon case, for the same system of construction has been largely adopted by gas companies in other places.

The general dimensions in the case referred to are as follows: Diameter of building inside of walls, 112 feet; height of upper ends of main rafters above top of walls, about 34 feet; diameter of ring near apex, 6 feet; length of main rafter, 63 feet; size of main rafter, 6 × 12 inches; distance between main rafters at base, on top of wall, about 11 feet on centres.

The main rafters were virtually in contact with each other where they abut against the ring of timber at their upper ends.

Their feet were tied in by horizontal rods, radiating from a central hub or ring, which limited the height to which the top of the holder

could rise. There was no trussing whatever above this level, the whole conical space of 112 feet diameter and 34 feet height being quite void, except that small suspension rods held the weight of the central ring.

Three lines of purlins were cut in between the main rafters at nearly equal distances, dividing the roof into four sections. These purlins were keyed against the rafters, and therefore formed a rigid regular polygon at each point, extending around inside the cone, being, when constructed, in horizontal planes.

As the roof was covered with tin, and too steep to allow much snow to accumulate on its surface, no exterior pressure was to be expected, except from the winds, and the whole structure was extremely light.

The principal rafters being some 63 feet in length, were composed of two planks, each 3×12 inches, bolted together, and breaking joints. Such a beam, when placed in such a position, is, of course, not capable of sustaining its own weight without great deflection, and probably not without fracture. The only support given it, however, between its two ends was that derived from the purlin-polygons or rings above described. So long as these purlins remained in their places, and formed regular polygons in horizontal planes, the roof was undoubtedly stable.

The engineer who designed it informs me that it was expected that the proprietors would watch the structure and correct any tendency toward distortion of form by tightening the keys between the purlins and rafters; but it is difficult to see how this would effect the object, and practically very difficult to get access to those keyed bearings without cutting holes in the roof cover from the outside. It must be remembered that the walls are over 40 feet high, and the tank filled with water some 20 feet deep at their base, in which floated the sheet-iron holder, the cover of which is not a suitable floor on which to erect staging or even ladders.

How long the roof kept its shape it is impossible to determine. It was so difficult of access that little had ever been done in the way of inspection, except to repaint the outside of the tin roof at intervals.

In the autumn of 1881 a tinman was sent on to it to repair some leaks and reported that the roof boarding was in some places so far below the tin and the exterior form was so distorted that he did not think it safe to work upon. An inspection of the frame from the top of the walls inside showed a similar state of things. Scarce any of the main rafters remained straight. Some sagged to the right and some to the left, and many more sagged downward. Their middle portion was estimated to be in several cases two feet out of a straight line between their ends, and the purlins by which they were connected were thrown out of their original horizontal plane in a zig-zag manner, giving one the impression of great instability. In fact, it is difficult to see what held up the roof except the tenacity of the boarding, which was nailed to the rafters. The purlins were all there, but acted no longer in any one plane, so that their support to the rafters was very indefinite. It was difficult at first to see how so much distortion could have taken place without a rupture. But a closer study showed that the sagging downward of any one rafter in its middle portion allowed its next neighbors to move toward it, sideways, as they were in fact found to have done, twisting the bearings without actually breaking them apart.

The impossibility of erecting staging from below rendered it difficult to readjust the frame: for the company could not spare the use of the holder at that season. Neither did it appear safe to allow it to remain during the winter, subjected as it would be to many high winds in its exposed condition.

The carpenter in the employ of the company was found to be willing to undertake the construction of a light stage, hanging it to the rafters by slings put through holes at proper points from the outside: and it was finally determined to support those rafters which sagged downward by applying a truss under each one in a vertical plane. It was found that 11 out of the 32 main rafters had such a downward tendency, being in three separate groups, on different sides of the cone. This grouping served to simplify the problem, for it enabled us to balance the dead weight of the trusses against one another, and avoid breaking up the poise of the whole roof, which might have been fatal to its stability if all the trusses had been put on one side of the cone.

It required about ten days to build a flying stage, hung to the rafters, without support from below the top of the walls during the process, and some three weeks more to apply the eleven trusses, moving the stage from place to place, as required. The truss adopted was of the Fink type, one strut at the middle and two at the quarters. The rafters were easily raised to straight lines by screwing up on the rods after applying the struts, and the roof thus restored to something like its original form, without removing its tinning.

The impropriety of such methods of construction is evident on general principles. For, although stability may be obtained when new, and for an indefinite period afterwards, its duration must of necessity depend upon the perfection of form of the whole frame and the keeping of the purlins in a horizontal position. In short, it is a delicately-poised structure, which may become unstable at any moment when an exterior force or any lack of uniformity of its materials succeeds in disturbing its perfect symmetry. So soon as any slight disturbance takes place, the stability soon vanishes. In short, it is in a condition of "unstable equilibrium" from the first, like all arrangements for *poising* materials above their base of support, without ample means of keeping them from initial motion.

The cost of applying trusses in vertical planes under each main rafter is not great if done as a part of the original plan. In the case referred to the principal cost was incurred by erecting the hanging stage and moving it from one place to another.

The iron work for the trusses cost only about $40 each.

If this roof is retained beyond the present season, trusses will be put under the remainder of its main rafters.

PROCEEDINGS.

FEBRUARY 15, 1882:—A regular meeting of the Society was held at 7.30 P.M., Vice-President Philbrick in the chair, and fifteen members present.

The record of the last meeting was read and approved.

Prof. Gaetano Lanza and Mr. Isaac M. Story were elected members of the Society.

Applications for membership were received from Philip D. Borden, Jr., city engineer, Fall River, proposed by Messrs. Lunt and Tinkham; from Richard A. Hale, Lawrence, proposed by Messrs. Freeman and Cheney, and from Lewis M. Hastings, Cambridge, proposed by Messrs. Barbour and Kimball.

The amendment to the first by-law, proposed at the last meeting, changing the evening of meeting from Wednesday to Thursday, was considered, but no action taken.

On motion of Mr. French, it was voted to recommit to the Government the question of changing time and place of holding the meetings, for further consideration.

The Government were authorized to expend a sum not exceeding $50 for binding periodicals and purchasing pamphlet-cases.

Mr. E. S. Philbrick read a paper on the Stability of Certain Conical Roofs.

After discussion of the paper, Mr. Rice read a letter from Mr. Fred Brooks (member of the Society), giving his experience in the use of the metric system on railroad work in Mexico, and pointing out the reasons why some had found difficulty in applying it.

Mr. Rice also exhibited a model of an automatic freight-car coupler, invented by Mr. Blanchard, of Boston.

[*Adjourned.*] S. E. TINKHAM, Secretary.

MARCH 15, 1882 :—The annual meeting of the Society was held at 7.30 P. M., President Thomas Doane in the chair ; seventeen members and one visitor present.

The record of the last meeting was read and approved.

The committees on Metric System and on Preservation of Timber were continued as at present constituted and given further time in which to report.

The Committee onClass-List of Engineering Books in Public Library presented a report which was read and accepted. The committee was continued and Prof. Wm. Watson was elected a member to fill a vacancy.

The annual reports of the Government and the Treasurer were read and accepted.

Officers for the ensuing year were elected as follows :

President, Thomas Doane.
Vice-President, Edward S. Philbrick.
Secretary, S. Everett Tinkham.
Treasurer, Henry Manley.
Librarian, Chas. W. Kettell.

Mr. Wm. H. Bradley, by vote, was appointed auditor.

It was voted to amend Article XVI. of the Constitution so that it shall read : During residence fifty miles or more from Boston, any member whose dues have been fully paid may, upon notice to the Secretary in writing, retain his membership by the payment of *three dollars* per year, payable at the annual meeting, and be exempted from any other assessment.

An assessment of $5 was ordered to be levied on active members.

The following resolution, recommended by the Government, was passed :

Resolved, That the Board of Managers of the Association of Engineering Societies be requested to increase the subscription price of its JOURNAL to non-members of the various societies.

It was also voted : That the income of the invested funds and the money received for entrance fees be added to a permanent fund and not used for current expenses.

The President was authorized to appoint a committee of three to solicit advertisements for the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

Messrs. P. D. Borden, Jr., R. A. Hale and L. M. Hasting were elected members of the Society, and Mr. Frank W. Hodgdon was proposed for membership by Messrs. Freeman and Tinkham.

Mr. E. W. Bowditch read a paper on the "Sanitary Aspect of Nahant, Mass."

[*Adjourned.*] S. E. TINKHAM, Secretary.

Annual Report of the Government of the Boston Society of Civil Engineers for the Year Ending March 15, 1882.

So far as known the Society has lost no member by death during the past year.

There have been held during the past year only the regular monthly meetings of the Society, ten in number, with an average attendance of 15. This is 2 less than that of the previous year and is to be accounted for by the more active professional employment of the members, many of whom have been called away from Boston, rather than by any want or lack of interest in the meetings.

The profession is to be congratulated both on the increased demands for its services and of increased remuneration for them.

The members of the Government of your Society were complimented by an invitation from the American Society of Civil Engineers to attend its annual meeting held in June last at Montreal, and several of them accepted the invitation.

The membership of our Society has been increased the last year by the election of 9 active members, while one member has resigned. The total membership is now 103, of which 93 are active, 2 corresponding and 8 honorary members. Fourteen members, absent from Boston, have availed themselves of the privilege of retaining membership by the payment of a fee of $2, as provided by the Constitution. It is thus seen that our active membership is increased by 8 over that of a year ago.

With the record of the June, 1881, meeting, the Society ceased printing its own proceedings, and since then the papers and proceedings have appeared in the Journal of the Association of Engineering Societies.

The most notable forward step taken by the Society during the past year, has been that by which it becomes associated with the engineering societies of St. Louis, Chicago and Cleveland, in the joint publication of their respective papers and proceedings.

The first number of this journal was issued under date of November, 1881. It makes a nice looking pamphlet of 56 pages. Without greatly adding to the cost of printing its own papers the members of this Society now have laid before them monthly, in proper form for preservation, in addition to their own, the papers of the St. Louis Club, having about 66 members, those of the Chicago Society, having about 126 members, and those of the Cleveland Club, having about 85 members, thus securing the best efforts of four societies, suitably located in important and widely separated centres in our broad country, having a joint membership of about 380.

The cost of this journal to the members is not yet certainly known, but it will probably be about $4 per year per member. It is now on sale to subscribers outside of the joint societies at $3 per year. Its success, professionally and pecuniarily, will turn on the interest which the members shall take in the publication, on the character and number of the papers contributed by them and on the amount of advertising secured for the Journal. It is hoped that the members of the Society will have a professional ambition to contribute liberally to the literary department of the Journal, and to handsomely carry its part of the joint responsibility.

And perhaps there can be no more fitting time or occasion to suggest to our honorary and corresponding members that this responsibility is resting upon them as well as upon the more active (so-called) members of the Society, and to say that the Government will be glad of any professional literary contribution from them which they may incorporate in the Journal.

Mr. Fred Brooks, on account of professional engagements elsewhere, resigned the office of Librarian. The resignation was accepted at the September meeting and Mr. C. W. Kettell was elected to the office.

The report of your Treasurer is presented herewith. From it you will learn that the receipts for the year have been $565.55 and the expenses $458.16, and the cash balance on hand for the new year is $377.29, being $107.39 more than at the beginning of the year just closed.

The Society has $1,200 invested in two Burlington & Missouri River R. R. bonds, yielding six per cent. interest.

For further details you are referred to the Treasurer's report.

It would be very pleasant if we were owners of a building in which we could go to housekeeping, where we could hold our meetings with none to molest or make us afraid, or disturb our thoughts, where we could collect engineering specimens and expose our library, now greatly shut up, and feel at home.

We are restricted by our charter to the ownership of not more than $20,000 in real and personal property. But should any of our active or honorary members feel disposed to do so good a thing for the Society, we have not a doubt that our legislature would so amend our charter as to permit us to hold a larger amount.

The Government has voted to make the following recommendations in its annual report to the society :

First.—That Article XVI of the Constitution be amended so that active members residing 50 miles or more from Boston shall pay $3 per year, to be exempted from other assessments, instead of $2 as now provided.

Secondly.—That an assessment of $5 be levied upon all active members.

Thirdly.—That a resolution be passed requesting the Board of Managers of the ASSOCIATION OF ENGINEERING SOCIETIES to increase the subscription price of its journal to non-members of the various societies.

Fourthly.—It was also voted that in the matter of changing the time and place of holding the meetings of the society, which was recommitted to the Government at the last meeting, it has no further suggestion to make and recommends that no further action be taken.

Fifthly.—It was suggested, but without action, that the income of our invested funds and the money received for entrance fees be added to permanent funds and not used for current expenses. Respectfully submitted,

THOMAS DOANE, President.
EDWARD S. PHILBRICK, Vice-President.
S. E. TINKHAM, Secretary.
HENRY MANLEY, Treasurer.
CHARLES W. KETTELL, Librarian.

BOSTON, March 15, 1882.

LIBRARY COMMITTEE'S REPORT.

The Committee on Class-List of Engineering Books in the Boston Public Library beg leave to present this brief report of the progress and nature of the work committed to them, and the prospects for its completion. It will, perhaps, be not inappropriate or without interest to recall the origin of the Committee.

Some years ago Mr. Chas. D. Austin, then a member of our Society, having in mind a very brief collection of titles of engineering works culled from the catalogue of the library by another member, was led to consider the great desirability of an extensive collection of all the works in the library relating to engineering matters, and on his motion, a committee of three was appointed for this purpose, the number being subsequently increased to five.

By this Committee considerable work has been done, with the aid of volunteers from the Society. The catalogues and bulletins have been examined up to some time in 1880, for the purpose of obtaining the titles of all the books in view, and the work has been divided into subjects, one or more of which have been given to different members of the Society, that they may examine as critically as possible the books in their special subject, with the view of determining, in some measure, the relative or absolute merits of the books, and so obviating the waste of time which every one has experienced in consulting any library.

The following subjects have been examined and are now nearly ready for publication, with the exception of such additions as have been made to the library since the subjects were examined.

That of Hydraulics has been prepared with much thoroughness by Mr. Brooks, who has also examined, in a similar manner, the subjects of Sanitary Engineering.

That of Bridges and Roofs is also nearly ready, and also the subject of Engineering Biography.

The following subjects have been committed, actually or in intent, to various members, but no report has been made as yet to the Committee :—Arches ; Retaining Walls ; Graphical Statics ; the Steam Engine ; Earth ; Stone and Masonry ; Artificial Stone and Concrete ; Iron and Steel, and others.

Some difficulty was experienced by the Committee in determining what form the publication should finally take. Some of its members desired to have an extensive description with critical remarks as to the value of the books ; in other words, it was desired that the catalogue should give just such information as any one who is an acknowledged authority upon the literature of any subject would give to a friend who called upon him for information as to the best book upon that subject.

In such a method of procedure, it would, of course, be necessary at times to animadvert severely upon some works, and for this reason, as well as for the reason that such a course would be distasteful to the library authorities, under whose co-operation the catalogue was to be brought out, this plan was in a great measure abandoned. It is hardly necessary to call attention to the immense amount of labor which such a critical and exhaustive catalogue would require.

It will be apparent from what has been said that much has been accomplished, even though more may remain yet to be done.

In the departure of Mr. Brooks to Mexico the Committee has met with a great loss. His untiring zeal, great organizing and analytical ability and more abundant leisure than others have had, fitted him especially for such work as this, and in his absence the rest of the Committee have been too much occupied to take up again the threads of the work and carry it to completion.

For the proper execution of such a work there is needed some one man who shall have the necessary leisure, ability, both scientific and executive, and lastly, the zeal to devote himself to the task.

He must be the leader and must direct the work and energies of the others, and of such volunteers as he can secure.

The Committee, therefore, while reporting the incompleteness of their work are impressed with its importance and the desirability of finishing it in a satisfactory manner. In the trust that such a conclusion may be reached they therefore recommend that the Committee be continued for another year and that Prof. Wm. Watson be added to its number at the request of its members.

For the Committee, C. W. KETTELL.

ABSTRACT OF TREASURER'S REPORT FOR YEAR ENDING MARCH 10, 1882.

Receipts.

Balance on hand at commencement of year		$269.90
Entrance fees		90.00
Assessment for current year, 71 members at $5	$355.00	
Non-resident dues for current year, 6 members at $2	12.00	
		367.00
Assessment for coming year	$5.00	
Non-resident dues for coming year, 11 members at $2	22.00	
		27.00
Interest on railroad bonds		72.00
Interest on current balance		8.37
Sale of Proceedings		1.18
		$835.45

TREASURER'S REPORT, CONTINUED.

Disbursements.

Rent		$50.00
Printing		186.92
Association of Engineering Societies, entrance fees	$44.00	
First assessment	98.00	
Printing Preliminary Proceedings	6.13	
	———	148.13
Binding		16.00
Postage and stationary		25.06
Periodicals		32.05
Cash on hand		377.29
		$835.45

Investment.

Two Burlington & Missouri River R. R. six per cent. non-exempt bonds of $600 each.

HENRY MANLEY, Treasurer.

ENGINEERS' CLUB OF ST. LOUIS.

ORGANIZED 1868

TRANSACTIONS.

ENGINEERING IN THE AUSTRALIAN COLONIES AND NEW ZEALAND.

By Onward Bates, Member A. S. C. E.

[Read February 16, 1882.]

I have gratefully accepted the invitation of your President to read before you this evening a paper on engineering in Australia and New Zealand, as it affords me the opportunity of bringing to your notice and recognition something of the efforts of our professional brethren at the Antipodes. It is impossible within the limits of this paper to enter into the details of so comprehensive a subject. I will, therefore, refrain from exhaustive criticisms and descriptions, and will endeavor to relate in a concise manner such of my observations made during three years of practice in the Australian Colonies as I think may prove interesting to the members of this Club. Australia and New Zealand are so far away that few of us have given them more attention than was bestowed in our early school days, and can have no adequate idea of their present condition of progress and prosperity.

These colonies have a superficial area of more than 3,000,000 square miles, and are populated with something over 3,200,000 white people. Their combined public debts aggregate more than $400,000,000, which fact alone appeals to the American mind as a proof of their importance. A large proportion of this debt was incurred for the construction of public works. For age and population, they are well provided with railways, roads and bridges, harbor and river improvements, public buildings and water-works. A visitor to the Colonies cannot fail to be filled with surprise at the character and extent of the public improvements.

The public works of each Colony are constructed and operated independently by their respective governments. Each Colony has a separate corps of engineers, the organizations of which are so similar that the New South Wales Corps may be cited as an example of them all. In that Colony the heads of engineering departments are the engineers in chief of railways, of roads and bridges and of harbors and rivers, the surveyor general and the colonial architect, each of whom has a large staff of assist-

ants, rendered necessary by the immense territory over which their operations extend.

The Colonials recognize the value and importance of railways in opening and developing their country, and these take first rank among their public works. The railways are, with the exception of two or three short lines, built and operated by the government engineers. In all of the Colonies there are in round numbers 4,000 miles of completed lines and 1,000 miles more under construction. The progress of extension varies in the different Colonies with the amount of money voted each year for that purpose by their Parliaments, though there is at all times more or less railway building going on.

New South Wales is at present taking the lead, its Parliament having voted in April last the sum of £7,326,500 for the construction of 582 miles of new railway lines. Although the Colonials are eager for the extension of their lines, they have yet to learn that railways are cosmopolitan, and that systems of connecting lines should as far as possible conform to each other, particularly in the matter of gauges and rolling stock. This is exemplified in Australia, where the railways, which will ultimately be all connected, are built by five different governments, with nearly as many different gauges. Thus, the gauges are, in Queensland, 3 feet 6 inches; in New South Wales, 4 feet 8½; in Victoria, 5 feet, and in South Australia 5 feet 3 inches and 3 feet 6 inches. These lines do not run through from the metropolis of one Colony to that of another, but meet on the boundary lines between the Colonies, thus breaking gauges near the middle of what ought to be trunk lines. The engineers are not altogether to blame for this, as the question of gauges is one of Government policy, and the engineer must build a road to the gauge prescribed by the Government. Governments like individuals are selfish and sometimes foolish, and in Australia, by breaks of gauges and discriminating tariffs, endeavor to control trade which would otherwise go to the nearest and best market, even if that market should be in another Colony.

These railways have been expensive to build, owing to the scarcity and high price of labor and the distance from centres of civilization, making materials and equipment costly. This cost has varied so much with the time and the circumstances under which the roads were built, that I am unable to quote any general figures. Colonial lines cost largely in excess of American ones, though the former are better constructed. This is especially the case with the permanent way, which excepting a few of our Eastern trunk lines is better than any in America. The engineers, as a rule, are Englishmen, and as most of those high in authority have been many years in the Colonies, they are doubtless even more conservative than English engineers are at home, and are not apt to deviate from old and safe customs for the sake of economy. The question of whether or not cheap lines are best to develop this country has not been solved. Mr. Ballard, the Engineer in Chief of Northern Queensland, is an advocate for the "American" system of railways, and has been very successful in reducing the cost of construction, and opening a larger extent of territory than was formerly done with the same amount of money.

Colonial lines are always well ballasted. Ballast is usually of broken rock and is laid to the level of tops of cross-ties between the rails and out-

side of the rails to the level of their tops. In some cases the ballast is confined laterally by a curbing of roughly hewn stone. Cross-ties are spaced farther apart and heavier rails are used than is the custom in this country. On some of the New South Wales railways double-headed rails are still used: these are fastened with wooden keys to cast-iron chairs, which are bolted to the cross-ties. Ordinary tee rails are now generally used. Sometimes these are fastened to the cross-ties with bolts instead of spikes. The engineers are suspicious of the light appearing bridges of the American type. As a consequence, instead of our bold location of lines resulting from the facility with which we can bridge streams and trestle valleys, their lines follow the contour of the ground, making a necessity of sharp curves and heavy cuts and fills. I recall to mind one piece of road in particular, where, by the use of viaducts, money would have been saved, and very much heavy work, including tunnels on reverse curves might have been omitted. As was mentioned in describing the gauges, the governments have much to do in determining the character of the railway lines, and these are not always built upon strictly engineering principles. This is not altogether an Australian peculiarity, as cases have been known in this country where boards of directors and general managers have overruled the judgment of their chief engineers. Last year there were some American viaducts built in South Australia, which, from their light appearance, were subjected to the profound criticism and condemnation of the unprofessional public. The engineer in chief reported to the government that they were of ample strength, and that their cost was much less than that of embankment, one-third that of colonial-built bridges and one-half what they would cost if imported from England. These viaducts have been a bone of contention in Parliament, and only recently a motion to have them removed and embankments 100 feet high substituted in their place was lost in that house. These viaducts, though called "American," have 30 feet plate-girder spans with buckle-plate floor, making a trough on legs, which trough is filled with broken stone and the railway track laid therein. The track is of 5 feet 3 inches gauge on a curve of 693 feet radius, and the superelevation of outer rail is 6½ inches, intended for a speed of 30 miles per hour.

Grades of 1 in 50 and curves of 10 chains radius for wide gauge and 5 chains radius for narrow gauge are common on most of the lines. It should be mentioned that a chain is 66 feet, as 100 feet chains are not used in the colonies.

Nearly all railway bridges are of iron. They are usually plate girders or lattice girders with a solid floor of wood or iron, and track is laid in ballast. Trusses are shallow, and in long spans have their tops connected at ends and centre with an arched strut. Continuous overhead wind bracing is not used except in some bridges recently imported from America. Continuous girders on three or more supports are common. These bridges with shallow trusses, heavy floor and load of ballast become enormously heavy in long spans. The longest railway span in the colonies that I know of is 180 feet.

Piers are commonly made of cast-iron cylinders sunk to rock or a hard stratum of clay and filled with concrete. Cylinders are imported from England, and for convenience of transportation are made in segments or

staves, the edges of which are planed. These are bolted together in position, and the joints calked with iron cement. Various methods are employed in sinking these cylinders. Some have been sunk by divers, others with the use of compressed air and air-lock on the principle employed in sinking the St. Louis piers, and where the nature of the bottom will permit of it, the excavation is done by dredging. "Milroy's" excavator and the clam-shell dredge have both proved serviceable for this work. After the cylinders have been sunk to a foundation, excavated and a test load applied, they are filled with concrete. Concrete is made with Portland cement, the proportions in some cases being 1½ of cement to 3 of sand and 5 of stone.

There is no fixed rule for the diameter of these cylinders. In one bridge, with 125 feet and 180 feet spans, the cylinders are respectively 5 feet and 7 feet in diameter. In some bridges with high piers, carrying 156 feet spans, the cylinders are 9 feet in diameter at top and 11 feet at bottom. In cast-iron cylinders the metal is from 1 inch to 1¼ inches in thickness. In some cases the bridge bed plates bear on column of concrete and rim of cylinder, in others on cylinder only, and in still others on concrete only. In the long bridge over the river Murray, at Echuca, the upper sections of cylinders are of one-fourth inch wrought-iron plates, and lower sections of cast-iron cylinders, with the flanges inside. These cylinders are lined with wood of thickness equal to the width of flanges, so the concrete shall have no bearing on the iron, and the whole load of bridge is carried on the column of concrete.

Experience has demonstrated that in the Colonies cylinder piers are more economical than if built of stone, and as they are not subjected to severe frosts, they appear to fulfill all their requirements.

Where masonry is used for piers, culverts or tunnel-lining it is of first-class, laid in cement.

Station buildings are substantially built, and are fenced in. At important stations the tracks are crossed with foot-bridges.

Instead of platforms at stations, a retaining wall is built alongside of the track, and filled at the back to bring the ground level with the floors of the cars.

The railway lines are fenced in. The fence is usually of wires, about 5 in number, strung on iron or wooden posts. On one of the Queensland lines this fence for both sides of the track, cost, erected, £141 per mile. Level highway crossings are avoided whenever possible. When it is necessary to have them, the highway is closed by gates, attended by a watchman.

In the place of round-houses for engines, they have "running sheds," covering two or more parallel tracks. These are inconvenient, as frequently requiring considerable shunting to get an engine out of the shed.

Great care is given to the maintenance of permanent way, and some of the lines are models of neatness in this respect.

In some cases engineering difficulties have been overcome in a praiseworthy manner, and some of the works are unique and worthy of a more extended description. The Great Western Line of New South Wales crosses a difficult pass in the Blue Mountains, with a series of "zig-zags" which require the trains to go forward and back alternately. There are

here steep grades and sharp curves, with portions of the line cut out of the mountain side and other portions carried by high, arched viaducts of masonry. This is probably the most expensive piece of railway in the Colonies, and I have never seen better work anywhere.

Through the courtesy of Mr. Maxwell, the General Manager of New Zealand railways, I was enabled to examine the "Fell" railway in that Colony. This is a short railway, $2\frac{3}{4}$ miles in length, on a mountain side, connecting the ends of the Wellington and Masterton line. Its office is to act as a sort of a vertical transfer between the ends of the ordinary railway, and its peculiarity consists in the "Fell" engines and the central rail upon which they operate. All passenger and freight cars are detached from the common engines and hauled this distance of $2\frac{3}{4}$ miles by the "Fell" engines. In addition to the usual rails there is a central horizontal rail which is gripped by the horizontal driving wheels on the engines. The track is of 3 feet 6 inch gauge, laid upon pine cross-ties 5 inches × 7 inches × 7 feet. A central longitudinal pine stringer 7 inches × 14 inch is bolted in 12 feet lengths to the cross-ties. About 12 inches above the stringer a heavy double-headed rail is fixed longitudinally by wrought-iron brackets bolted to the stringer. The lightest gradient is 1 in 15 and the steepest 1 in 13, with the exception of a distance of 2 chains, where it is 1 in $11\frac{1}{2}$. Most of the line is on curves with radii varying from 7 to 12 chains. The engines are built by the Avonside Engine Co., of Bristol, England. They carry a pressure of 150 pounds of steam and have two outside cylinders 14 inches × 18 inches, working two pairs of driving wheels as in common engines, and two inside cylinders 12 inches × 16 inches working two pairs of horizontal driving wheels which grip the central rail between them. These wheels are provided with powerful springs pressing them against the rail. This pressure can be varied at pleasure, and the wheels may be made to act as a brake if necessary. The "Fell" engines will draw as many as 10 loaded goods wagons up the incline, but their usual load consists of 7 wagons loaded with 6 tons each. At the opening of the railway to Masterton 3 of these engines hauled 24 of the largest carriages containing 1,400 passengers.

The time occupied each way in traversing the distance of $2\frac{3}{4}$ miles is from 25 to 30 minutes. A brake van with appliances for grappling the central rail is attached to each train, whether of passenger or freight cars. Passenger carriages are always pushed ahead of the engine to prevent discomfort to the passengers from smoke while passing through the tunnel at the summit of the incline. About a year and a half ago an accident happened on this line which well illustrates the grip the "Fell" engine has on the central rail. An engine with two passenger carriages and brake van in front, and two covered goods wagons and brake van in the rear, was ascending the incline, when the passenger carriages and front brake van were lifted bodily by wind and blown over a high embankment, where they hung suspended by the couplings from the engine, which remained firmly clamped to the central rail. There was no loss of life and small damage to the carriages, which, thanks to the strength of the couplings, hung safely until removed. I was unable to obtain figures of the cost of operation and repairs on these engines, both of which are necessarily heavy in so complicated a machine. The facility afforded by the "Fell"

engines, where very steep grades are necessary, invites for them the careful consideration of engineers.

Until recently, the Colonial rolling stock has all been obtained from England. Now American engines and passenger cars are forcing their way into favor, notwithstanding British prejudices, which are especially strong in this direction. American engines are in daily use in Queensland, New South Wales, Victoria, South Australia and New Zealand. American passenger and sleeping cars are run in New South Wales, South Australia and Victoria, and are so well liked that shops have been built in Sydney for their manufacture. In some cases the four-wheeled English cars have been replaced by longer ones of the same pattern, with bogies under their ends. Cleminson's system of radiating axles with three pairs of wheels under a car has been successfully used in South Australia, and these cars are now manufactured in Adelaide, upon an improved design of Mr. Mais, the engineer-in-chief of that Colony. Their English passenger cars have lateral seats the full width of the cars, with doors at each side, and are divided into first and second-class compartments. There is no communication between the compartments, or with the engine or brake van. With the exception of some of the passenger trains, which are equipped with the Westinghouse continuous brake, the only brakes on a train are on the engine, and on the guard's van at the rear of the train. Freight cars, or goods wagons as they are called, are 4 wheelers, with sides and ends as on a gondola car, though deeper. Perishable goods are covered with a tarpaulin. Car wheels are of wrought iron, with spokes, and iron or steel tires. Cast-iron wheels are not considered safe but it appears wrought-iron wheels will also fail at times, as was shown in a late accident on the Hobson's Bay Railway in Victoria, where a combination of wrought-iron wheels and only 4 under a car, and no communication between passengers and engine driver, resulted in the death of three people and great loss of property. In this case a tire broke and came off, the wheel running on the spokes and jolting the passengers for a sufficent time before the derailment of the train, to have stopped the train if there had been any means of notifying the driver that an accident had happened to the car.

There is a marked difference between "railroading" in America and in the Colonies, from the construction of the lines to the management of the goods traffic. Every American knows a good deal about railroads, and if it happens to be his luck to be locked up in a small compartment for a long journey on a Colonial railway, he will see and hear much that is novel and interesting, and possibly the discomfort of the trip may bring to his notice some things which he feels himself competent to criticise.

The railway from Hobart Town to Launceston in Tasmania is something over a hundred miles long. The passenger train leaving Hobart Town at six in the evening, stops at a little bit of a way station at the half-way point two hours, in order not to arrive at Launceston and disturb the officials at that end before seven in the morning. I had the opportunity during those two hours of making some solid reflections on railway management.

Even the technical terms are all different ; switches are called points.

rails are metals, firemen are stokers, conductors are guards, buying a ticket is booking, and so through the list *ad libitum*.

Colonial railways are monopolies, and if one of their lines were taken up and sandwiched between two competing American lines, the chances are it would be managed very differently, and the change would be for the benefit of the public who patronize it. More than 20 years ago, George Francis Train built a street-car line in Sydney which for some reason, good or bad, was condemned and taken up. Since that time street-car lines or "tramways" have become an institution in the Colonies, and these are some of their "points" that Americans may profit by. The principal of these is the maintenance of the street between the rails and for some distance each side of the track. The same care which is characteristic of their railways is given to their tramways. In the construction of the lines they start with the first essential for a good road of any kind, that is, a foundation, and they build and maintain the roads with great care. The rail generally used is the "Larsen" shape of heavy section.

The cars and the methods of propelling them vary in the different cities. In Adelaide may be seen John Stephenson's New York cars drawn according to their size, by two or three horses abreast. In Sydney steam motors are used. These are small locomotives housed in to resemble cars and they draw one or more passenger cars as may be required. The Baldwin Locomotive Works, of Philadelphia, have sent out for the Sydney lines more than thirty of these motors. The cars on these lines are of all patterns, American and Colonial, single and double-deckers, open and closed; the largest cars have seats for 70 passengers. There are tramway lines in Wellington, Christchurch and Dunedin. These are variously propelled by horses or motors. In Dunedin there is one of Mr. Halliday's wire-rope tramways on a street where the grade is too steep for horses or motors.

So much of this paper has been devoted to railways that it will be necessary to make the mention of other departments of Colonial engineering very brief.

The engineer-in-chief of roads and bridges for New South Wales has in his charge more than 900 miles of highways with all of the bridges incidental to this length of roads. In addition to this he is also engineer for the system of sewerage of the city of Sydney. I can only speak of the roads by complimenting them generally. They are spread over a large territory, and considering the scattered population are most creditable to the Colony. In his department are a great many bridges, a large proportion of which are of iron. Some of these are built 500 miles in the interior. One of the largest was recently built by the Edgemoor Iron Company of Wilmington, Del. This bridge is for both highway and railway, is 21 feet wide in the clear and has seven spans of 125 feet and one of 182 feet. It rests upon iron cylinder pins. More than 150 cylinders have been sunk for pins in this department. The bridges in many cases have a tight floor, upon which a roadway of finely broken stone is placed.

The highways throughout the Colonies may be commended, and some of them are as good as may be found in any country district of America. The city roadways are not proportionately good, though one would not have to go a thousand miles from St. Louis to find worse. In making a

street, it is excavated for a couple of feet and a foundation of broken stone put in with the flat sides on the clay. This is filled up with smaller stone, and the roadway is finished with finely broken stone well rolled with a steam roller. This makes a tolerably fair street, and it has the advantage that the bottom never drops out. All repairs are made on the top or wearing surface. In some cases the same foundation is put in, and the top is made of bluestone cubes or sets packed on sand. This is a noisy pavement though very durable. It is this class of pavement that is put between and on each side of the street-car tracks.

A portion of one of the principal streets in Sydney is paved with asphalt blocks imported from America. This is, I believe, the same pavement that is now being manufactured in this city. Wooden pavements have recently been tried in Sydney as an experiment, with the belief that the hard Australian timber would make a good and durable pavement. This has not been in use long enough to justify an opinion on it.

The Department of Harbors and Rivers has the direction of all improvements for navigation of streams and bays and of the water supply of the principal cities, the construction of light-houses, etc. Large amounts of money have been expended in dredging channels. This is usually done with dredge boats fitted with endless chains and buckets. Some of these boats have been very carefully designed, and have proved most effective. An idea of their size may be taken from the consideration that some of them built in the Colonies have cost £28,000 each. In the construction of wharves in salt water the timber has to be sheathed with copper or muntz metal, as the teredo is very destructive in the Australian and New Zealand waters. In the harbor at Sydney a fine and expensive wharf has been built upon cast-iron cylinders filled with concrete. The water-works, light-houses and other works in this department require a more extended description than I am able to give them in this paper.

All of the governments have same grand public buildings constructed under the direction of their "Colonial Architects." Stone and brick are the principal building materials, the best buildings being built of stone. There is an exception to this in the public buildings of Wellington, the seat of government in New Zealand, which are built of wood, as it was feared the frequent earthquakes to which that locality is subjected would injure masonry structures.

This department of engineering differs from those before mentioned, in that while they are almost exclusively controlled by the government engineers, there is plenty of scope for architects in private practice, as is shown by the numerous fine churches, business houses and private residences in each of the principal Colonial cities. The Colonials do not run as much to pasteboard houses as we do. Their houses are substantially built, with thick walls and solid partitions, and in consequence are comfortable and safe. This does not apply to some of the hotels, where the bed-rooms are so small it is next to impossible to get an American trunk into them. A feature in the business houses is the small doors and windows. They get heat and light mixed, and in their efforts to keep out the former, exclude too much of the latter. Immense quantities of galvanized, corrugated iron are used in sheds and the cheapest class of buildings. I have thought that the use of this material might be extended in this country.

The Colonies are well provided with telegraph lines. The construction of the overland telegraph line running north and south from Adelaide to Port Darwin, through a country which is almost a desert, was an engineering work of no small magnitude, and one of great personal hardship to those employed upon it. From Port Darwin there is a cable connection with Europe, and the Colonies of Tasmania and New Zealand are connected by cable with Australia.

The Colonies are well supplied with coal and iron ores. Iron is not yet manufactured to any extent. Nearly the whole of the iron of every description is obtained from England. The low first cost in England and cheap freights have so far put Colonial competition almost out of the question. Freight charges from England or Scotland to Sydney, upon rails, bridges, etc., for the government, are generally less than $5 per ton. Each Colony levies its own duties, which vary from free-trade in New South Wales to an almost American tariff in Victoria. The duties are variable quantities, and are liable to be changed by any government which happens to be in power. The coal, which is bituminous, is extensively mined, and a large surplus is exported.

The principal building stones are sandstone and bluestone, the latter being a basalt of volcanic origin. Sandstone of fine quality is abundant in many localities, and from the ease with which it is worked it is largely used in construction. There are some magnificent buildings of this stone, and on the New South Wales railway lines there are some very large and handsome viaducts constructed of it. Bluestone is by far the most durable, but, from its irregular fracture, is very difficult to work. It makes excellent road metal and ballast.

The constructive timbers of Australia are the eucalyptus or gum, Australian cedar and pine. Cedar is scarce; it is a handsome wood, and is used for furniture, doors, windows and similar purposes. Pine is also scarce and it not used to any great extent. Gum is almost the only engineering wood. It is distributed over Australia and Tasmania, and grows in different localities from a stunted shrub to a height greater than is recorded of the big redwood trees in California, though not so large in girth. There are a great many varieties of gum, some of which are so similar that even botanists find a difficulty in distinguishing them. The same variety will differ when grown on high or low ground. Also, the same tree is known by different names in different localities; thus, blue gum in one district may be red or spotted gum or something else in another district. The gums have a great tendency to shrink and warp. They are said to shrink lengthways. This may be accounted for by the curly grain in many varieties, which for the same reason does not make a safe beam. The best varieties are iron bark, blue, red, and spotted gum, black butt, stringy bark and Jarrah. They are all hard, heavy and durable woods. These woods are so hard they must be bored for nails and spikes. Wrought nails are used in consequence, and cut nails are unknown in Australia. Iron bark is the best of the species. It is a very hard, strong wood of a red color, and weighs from 60 to 65 pounds per cubic foot. It is obtained principally from New South Wales and Victoria, and much of it is exported to each of the other Colonies. Large quantities of Jarrah are exported from Western Australia into South Australia,

where it is used for cross-ties, bridge timbers and similar work. The bark from the stringy bark tree is taken off in sheets as large as 4×10 feet, and is used for the roofs and sides of houses in the rural districts. The blue gum is called the fever tree, and is said to ward off fevers and prevent diseases. It is claimed that its introduction will convert a sickly locality into a healthy one. Numbers of these trees have been transplanted in California, where they thrive and appear to meet with favor. They are of rapid growth and make good timber, and may prove a valuable acquisition to our timbers.

The principal New Zealand timbers are tatara, black pine and kauri pine. These timbers are all valuable, but for important works Australian iron bark or red gum are frequently specified. Large quantities of gum from the kauri pine are brought to New York, where it is made into varnish.

Besides the native timbers, Oregon pine is greatly esteemed, and may always be obtained in the principal cities.

In some portions of the country, notably in South Australia, white ants are very destructive to timber. They eat up cross-ties and bridges, and even wooden houses. This is one reason why so much galvanized iron is used, and for the same reason the telegraph poles are generally of iron. A preservative process that is cheap and will apply to hard, dense woods and afford a protection against ants and teredo would be extremely valuable in Australia.

There is great prejudice in the Colonies against the employment of any but white labor. On the sugar plantations of Queensland Kanakas (South Sea Islanders) are worked, but these are little better than slaves and the method of obtaining them is questionable. On engineering works, white labor, principally British, is employed exclusively. It is the custom for the men to live in tents, which they can comfortably do at all seasons of the year. In Australia it is never cold, and the hottest weather is not as enervating as our St. Louis summers. It is a delightful climate to work in, yet my experience tends to the opinion that it makes people indolent. Eight hours constitute a day's work, and a year ago when I was familiar with wages, contractors were advertising for navvies at nine shillings per day. This is good wages when you need scarcely any clothing and can buy a tent to live in for \$5 and get good mutton for 5c. a pound and flour at \$1.50 a bushel. Labor is said to be plentiful, but I should call it scarce. When deputations of the so-called unemployed were hammering at the doors of the government for relief, I could not get the commonest labor for less than ten pence per hour. The skilled labor of the Colonies is well paid, and is more than usually cursed with unions. Capitalists are afraid to invest in enterprises requiring their assistance, and thus their unionism cuts both ways.

During my stay in the Colonies, where I was filled with thoughts of home, and, having to combat with some old fashions and customs, I naturally saw much to criticise, and in my own mind, condemn. I wish to state here that I also saw a great deal to admire, and trust it has enabled me to cut off a little of my American bigotry. I don't believe in the government having the exclusive control of engineering works. It creates a monopoly, and does away with competition, which is not

only the soul of trade, but is also the tumbling-board that brightens an engineer's wits. The independence of the government engineer is lost, and he is bound hand and foot with red tape. On the other hand, there is small temptation for him to do bad work, and I have never seen any inclination on his part to accept such work. They demand good work, and generally get it. They deserve great credit for their public works, some of which were carried out under special difficulties, resulting from the isolation of the locality. I trust that in this paper, no matter how badly it is written, I have given a sufficient account of antipodal engineering to lead you to the same favorable opinion which I entertain.

WESTERN SOCIETY OF ENGINEERS.

ORGANIZED 1869.

TRANSACTIONS.

ADDRESS OF E. S. CHESBROUGH, RETIRING PRESIDENT.

Gentlemen of the Western Society of Engineers:

Our Society, which originated about thirteen years ago, may be said to have passed during the year 1881 through the trials and dangers of a new birth, consequent upon the recent changes in its organization and the wider aims then adopted. Instead of being in name simply a local club, expecting a membership from but a limited territory and looking apparently only to civil engineers for accessions, it has adopted a title which will apply to more than one-half of our national domain and to all who are, or have been, employed in carrying out the principles of engineering.

The first half of the year was much taken up with the discussion of measures. The most important result has been the union now existing with the Boston, Cleveland and St. Louis societies, in the formation of an association for the publication of the proceedings of the societies thus united. If the character and appearance of the numbers of the JOURNAL OF THE ASSOCIATION thus far published, and the proverb "In union is strength" can be taken as grounds of prophecy, we may predict an encouraging and creditable future for it. How shall such a journal be sustained? Money can generally be obtained by wisely directed appeals, and interesting matter for publication can be procured by compilations from existing treatises and articles of acknowledged value: but unless we can furnish for the JOURNAL papers containing at least some original matter of interest in some branch of engineering, then, as far as we are concerned, such a publication will fail in its most important object. The three essentials to our prosperity are increase of membership, a greater amount of income, and the frequent production of articles worthy of publication and likely to be valued by engineers interested in the subjects treated. Other things are very desirable, such as permanent, well-lighted, comfortable rooms, a good reference library, and sufficient means to keep the rooms and library always accessible and serviceable to the members. If, however, we do not yet possess these things, or owing to our position with regard to kindred societies, or to our peculiar surroundings, our growth should be slower than we hoped for, we ought not to be discouraged.

Having first settled it firmly in our minds that the best interests of a

large number of engineers demand an organization whose meetings should be held in this city, duty requires us to sustain such an organization. We have already a membership sufficiently large to produce many valuable papers. The character of these is what must determine our usefulness outside of our membership. "What should be our highest aim as engineers?" Should it be to stand at the head of the profession, or to scrupulously discharge the duties of the positions in which we are placed? If the former, then we have many chances of failure to one of success, which will so often depend upon circumstances entirely beyond our control. If the latter, then success depends upon ourselves; for it is assured by a simple and constant attention to the requirements of each occasion as it arises. Of course, this implies honesty not only in the discharge of duty, but in a careful preparation for it. When the attainment of the highest position is the all-absorbing or controlling motive it may lead to injustice to others, to seeking their positions, or to claiming credit not deserved The true engineer will shrink from all of these and, as a rule, make but little if any claim to credit, leaving it to others to say what he deserves. He will occasionally discover quite a diversity of opinion on the subject, especially if the press should take it up: but if he is prudent he will keep out of the controversy.

We should be ever ready to help and advise each other, to strengthen private judgment: but this should not be carried to the point of giving to employers responsible professional advice for which they do not pay. This would not be mentioned if some cities and towns did not endeavor to get valuable advice from engineers without paying for it, when they would not expect to get it in a similar manner from doctors or lawyers.

Engineers are often depressed with a sense of injustice in regard to their pay and relative position among the officers of a city or corporation, or as compared with the members of other professions. Salaries are sometimes cut down so as to make it impossible for an engineer to live in a manner befitting his position or to properly educate his children. A remarkable instance of cutting down has been reported lately. In a city containing many intelligent and enterprising men, the office of city engineer was let out to the lowest bidder at $900 a year. No wonder the "successful competitor" is said to have employed as rodman a boy only 8 years old! If a distinguished surgeon or lawyer should charge several hundred dollars for a few hours' work, it is acquiesced in as a reasonable compensation for professional knowledge, experience and ability: but if an engineer should make corresponding charges, he would excite astonishment, at least in this country. But these things cannot be changed by merely speaking against them; and there is an encouraging side. If the increasing number of engineers who have recently been placed in positions of great importance, as presidents and vice-presidents, general managers and general superintendents of railroads and other corporations, may be taken as a guide, it is not unreasonable to hope for a return to the custom that prevailed fifty years ago, and later, of giving the charge of operating completed works to those who had constructed them. At all events, such a state of things is much more likely to be brought about by the exercise of the kindly feelings and scrupulous regard to duty before mentioned among engineers themselves than by the

opposite or purely selfish course. Even if promotion and pecuniary prosperity should not result, the advancement of engineering certainly would, and this means advancing the interests of mankind. To be a benefactor to one's race should be, and is by right-minded persons, considered more honorable than the mere possession of wealth or position.

In regard to the progress of engineering during the past year, a statement of which is expected of the retiring president, it is not an easy matter to tell where to begin or where to end. In every branch of engineering there are units of measu e or standards of comparison. How shall we apply them in this case? As with the heavenly bodies, actual progress can only be determined after a long series of carefully made and considered observations, so in the latter a knowledge of and careful comparisons with the past are essential to a determination of actual progress as well as its measure. If we consider the amount of engineering works constructed during the past year as evidence of progress, then it was probably greater than in any previous year in the history of the world. But mere repetition or duplication, however extensive, cannot be considered real progress in engineering any more than a multiplication of books in successive editions can be considered progress in literature. We cannot help associating with the idea of progress something new either in principle or combination. What can we find in these respects to apply to the past year? If we might look back but a little more than fifty years it would be easy indeed to prove that there has been great progress. Allusion only will now be made to recent progress in a few directions.

Descriptions of most of the works now in progress or contemplated have appeared in the numerous weekly and monthly journals with which engineers are so well supplied. It would be difficult to point to a more striking evidence of the progress of engineering than the number and character of most of these journals, which could not have been sustained a few years ago.

The enormous loss of the force residing in coal when applied to useful effect through the steam engine, continues to exercise the ingenuity of inventors, and the number of abandoned contrivances for saving fuel is constantly increasing. The most promising direction in which to look for a saving of some part of the great loss of force now experienced continues to be in the use of steam of higher initial pressure. This has led to increased strength of boilers; but the use of steel of excellent quality now produced at such low comparative rates, makes it as easy and as safe to navigate the ocean with steamers having boilers bearing 100 pounds pressure as it was with those having but 10 pounds pressure forty years ago. Even less than the pressure of the atmosphere was advocated by naval men, so that in time of war, a ball through a boiler, instead of letting steam out, would let air in. The newspapers last year published accounts of a steamer which crossed the ocean to this country, the "Anthracite," that had a boiler pressure of 300 pounds. How long it will take to introduce such a pressure generally, it is useless to speculate upon. The reintroduction of compound cylinders, so long laid aside, while not increasing the duty of the steam engine theoretically, does increase it, by making it practicable to use the expansion force of steam to a much greater extent than formerly. Actual ex-

perience has caused all the leading lines of Atlantic steamers to be provided with engines of this type. For stationary engines, such as pumping-engines, the tendency is in the same direction; but for most other purposes such a tendency cannot be claimed, the question depending upon such considerations as first cost, rate of expansion desired, and size and purpose of engine.

Substitutes for the steam engine do not appear to have made much advance. Yet at the close of a lecture recently by the Electrician to the General Post-office, London, Sir William Thomson said at Glasgow: "The steam engine was passing away and the gas engine would supply its place." Thus far progress in that direction on a large scale has been very slight. Ericsson's small caloric engines are said to be manufactured quite extensively; their extreme simplicity, being without valves, makes them very desirable for many purposes. If Sir William's views are realized, "we must look forward to a time when, instead of getting up steam, fire will be applied direct to do the work." Also that "three years ago scientific men, who should have seen such a thing beforehand, but did not, scarcely credit what has now been shown by engineers, that gas used to drive a gas engine and produce the electric light, gives much more light than when used directly."

Of the increase in the number of miles of railroad in this and other countries during the year it is impossible to speak with certainty, except to say that it exceeds that of any former year; and is therefore the most striking measure we have of the increased application of engineering works to the wants of mankind. The effects of this increase, though at once great, cannot be limited to the present. The numerous important links that are to form connections between the Atlantic and the Pacific, beginning with the Northern Pacific and going southward, not merely to the Southern Pacific, but passing over into Mexico, have made great progress.

In the crossing of mountains, steep grades continue to be adopted. By increasing the weight and number of locomotives, and resorting to tunnels when necessary and loops when practicable, it would seem as if there were no mountains in the world which might not be traversed by the locomotive. We hear of the 90-ton locomotive, including tender, on the Pacific slope. When this is compared with the 5-ton engine, considered heavy fifty years ago, we see great progress.

If no marked change has taken place in the forms of railroad equipments recently, they have been benefited by the improvements made in the manufacture of materials, especially in the use of steel, which for rails continues to show the great superiority and economy, as compared with iron, claimed for it years ago.

The enormous increase of business on the leading lines of road calls for terminal facilities in large cities not dreamed of when the railway system was commenced in this country.

No branch of engineering requires more skill and care than that demanded in some cases for the renewal or repairs of bridges on railroads over which the regular trains must not be interrupted if it can possibly be avoided. Probably the most remarkable example of this kind in our country is the late thorough repair and renewal of parts of the Niagara suspension

bridge. In a recent case, where the fall of part of a bridge interrupted traffic, it is said the losses were a million dollars or more, whereas could the renewal have been made without interrupting traffic the cost would not have been $100,000.

The prevention of accidents on railroads has always called forth much ingenuity and care: yet some of the most fearful that have ever happened have occurred recently. The block system is extending and is the most certain means known for preventing collisions of trains, but its heavy expense has prevented its general adoption thus far in this country. Experiments are now in progress for determining the practicability of substituting automatic electrical apparatus to a still greater extent for a part of what is now done by men. The frequent examination of bridges has no doubt led to the prevention of many calamities, and yet several recent instances of serious accidents occurring at bridges shortly after their examination, make it painfully apparent how easy it is to overlook vital points. Accidents and failures lead to renewed study of their causes and thus advance engineering knowledge, though sometimes at a fearful cost of life and money as well as great grief and mortification to those who are held responsible for them. It is very easy to point out the defects of a structure after it has failed; but only those who point out such defects before the failure, and especially during the planning or construction of the works, deserve much praise; for after everybody becomes familiar with a fact, there is little credit in promulgating it.

One important element of danger on railroads, especially to bridges, is the gradual yet in the aggregate great increase in weight of engines and cars, and speed at which they run. Structures which originally had a large factor of safety have had it gradually diminished to nothing, not only from the causes mentioned but from deterioration or defects of materials not originally suspected, while theoretically they were still safe.

The actual progress in bridge building during the past year is said to consist, not in the discovery or carrying out of any new principles, but in the more perfect adaptation of those principles to all the parts of such structures. Decided improvement has been made in the strength of materials and modes of testing it, and the forms and proportions of parts, now considered almost perfect.

The Brooklyn suspension bridge, though not yet finished, and up to this time the most remarkable bridge in the world, having a centre span of about 1600 feet, seems likely to be eclipsed by the wonderful bridge planned for crossing the Forth, which has two spans of 1730 feet each. The novel and exceedingly bold application of principles, long known to engineers, in its plan, if carried out, will make it the most extraordinary bridge in the world.

In regard to the deterioration of material in bridges, much and rather surprising information has recently been collected in this city, the particulars of which, it is hoped, will yet be published. Structures which were planned by able and competent engineers, with whom they were a specialty, have been found unsafe, from the effect of acids escaping from the furnaces of locomotives and other engines. Dangers of this kind, like many others, when expected are easily prevented.

The subject of sewerage, so intimately connected with the health and comfort of the inhabitants of cities and towns, has probably been written about more the last year than in any preceding one; but it is difficult if not impossible to point out anything in principle or essential features that was not known years ago to engineers familiar with this branch of their profession. The separate system, now about forty years old, has come into special prominence. It seems likely to be carried to an extreme, but will no doubt furnish valuable experience. In the disposal of sewage all the methods now resorted to have been known in substance, if not in minute detail, many years. The ventilation of sewers through perforated covers into the streets is now almost universally adopted, though strongly opposed not long since.

Although nothing new in principle in this department can be pointed out, much has been recently done in the planning and construction of new works, and in collecting information concerning the experience of cities that have had them for some time. Among our own countrymen, Mr. Hering has made an exceedingly valuable contribution to our knowledge by the recent account of his observations on the sewerage works of European cities.* It is expected that a completely illustrated edition of his report will soon become accessible to all. The experience of such cities as London, Paris and Berlin should be carefully studied by the engineer who would avoid serious errors in the planning of work for our own large cities. Yet there is much, and soon there will be more, to learn from experience in this country, especially in the disposal of sewage. Among works carried out for this purpose the past year are those of Pullman, so near us and the first of the kind in the West, and the most complete in the United States. From their operation it is believed much valuable experience will be gained for this vicinity, which has its peculiar climate and soil, while much of it, like Pullman, is very slightly elevated above Lake Michigan.

In many cases the engineer is perplexed in determining what to do to provide for future extensions. This difficulty is not confined to the planning of sewerage works, but is particularly troublesome with them. It is reported the lower parts of London suffer now from the flooding of cellars by excesses of storm-water not originally anticipated or provided for, but which are consequent upon the remarkable growth of that metropolis.

Paris is gradually extending her irrigating system by encouraging farmers to use the sewage, which they find so profitable. Berlin is making satisfactory progress with her extensive, but as yet partially carried out, irrigating system. Reports speak very favorably of the salubrious condition of the farms and value of crops raised upon them. It is believed that these will soon yield a sufficient net revenue to pay a reasonable profit on the cost of the farms, together with their improvement and maintenance, but not upon the cost of the works for delivering the sewage at the farms.

Contrivances for flushing and cleansing sewers are now more perfect than ever. For the improved sewerage of Boston extensive experiments

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* Reprinted in *Western Engineer.*

have been made with cements.* One result was the curious as well as probably important discovery that a limited addition of pulverized clay to Portland cement increased its strength and imperviousness. If this should prove to be the case with other clays, and time show no deterioration in such mixtures, they will not only reduce the cost of Portland cement mortars, but add to their value for dams and reservoirs as well as sewers. A somewhat similar discovery is said to have been made at Providence several years ago, but the subject was not further investigated there.

The remarkable extent to which water-works have been introduced into the cities and towns of our country has been shown in regard to most of them by Mr. Croes, whose descriptions of their details† are already well known, and, like Mr. Hering's report, will make a very valuable contribution to our knowledge, and be a work of reference for many years to come. Such papers form a safe basis for progress, and it is well that some engineers of the requisite qualifications can find time to prepare them.

The new works for supplying Liverpool with water, commenced last year, it is believed are the most important now under construction. One or two facts in regard to them are of special interest. Besides tunnels and inverted syphons, now so well known, the reservoir which is to collect the supply is to be formed by a stone dam about 800 feet long and 80 feet high above the surface of the ground, and extending 40 feet below to bed rock. Although stone dams are not new, even those of much greater height than the one at the head of the Liverpool works, they have not, in this country, been much in favor for considerable heights. Occasionally one has been recommended and adopted here, but the partiality for earth dams has generally prevailed, and in many cases is justifiable. But for very high dams, where a rock foundation can be reached, investigations in Europe and in the East Indies have settled the question that stone dams are much more advisable than earthen ones. The Furens and the Ban dams, in France, each about 164 feet high, have now been constructed long enough to add the testimony of experience to that of theory on this subject.

Another fact in connection with the Liverpool water-works is this: Notwithstanding the saving of water brought about by the Deacon system in that city, her extensive and costly new works have been commenced. This leads to a mention of the waste of water in cities generally; but there is not time to discuss it here. Yet there is nothing in connection with the management of works that calls so loudly for reform. Why cities should use from 50 to 125 gallons per inhabitant a day, when in the latter case two-thirds or more must be waste, is a very difficult question to answer on any reasonable or economical grounds, yet the attempts to prevent this waste are generally hedged about with difficulties that soon discourage or render powerless those who make them.

Hitherto electrical appliances have not been considered as coming within the special care of the engineer, but the field of invention they

* It is hoped an account of these will soon be published.

† See *Engineering News.*

have already opened up has become exceedingly large, and covers a great deal that is inseparably connected with engineering works.

As a motor for locomotives or other engines, but little or no progress has been made in their general introduction except for those of very small power, to generate which steam must be used: but when water can be used, transmission of power by means of electricity to a distance will no doubt be rapidly developed hereafter. As by using the electric telegraph it is possible to do so much more business and with greater safety on railroads than formerly, so with the telephone all kinds of business are more rapidly and easily transacted between different parts of a city, and there is reason to believe this will be practicable before long between different cities. Already they have conversed through 600 to 700 miles of coiled cable, experimentally, and actually between the cities of New York and Buffalo—400 miles.

In the production of electric light we are often struck with new applications of beauty and brilliancy, especially in New York, Chicago and other cities, where some of the streets at night are made almost as light as day. By means of the electric fire alarm in Chicago, the time required to start horses and engine after the signal has been given has been reduced to less than eight seconds. Besides the rapid extinguishment of fires, electricity is proving a most efficient aid in the prevention of crime. The stranger or returning absentee is struck with the present efficient arrangement for massing police with great rapidity in any part of this city.

What to do with the telegraph and telephone wires has become a serious problem in American cities: the tendency to put them underground being on the increase. This is already done in European cities. In Paris, the sewers, which are much larger in proportion than in any other city, are utilized for this purpose.

The uses to which electricity have been and may be applied are so numerous already and increasing so rapidly that one is tempted to give strong play to his imagination in forecasting the future. By means of this wonderful agent Niagara Falls could be made to put out fires in New York and other cities: move the trains on many railroads, give light to millions of inhabitants and heat to their dwellings, besides accomplishing hundreds of other useful purposes. If the efforts now made by very able and hopeful men to store up this mighty and yet manageable force should succeed, it is impossible to set bounds to its uses. In some form or another electricity seems destined to enable men to navigate the air. When this is accomplished it will be easy to do more in exploring the Arctic and Antarctic regions in one year than has been done in a thousand hitherto. The geography of Africa will be known in a short time as thoroughly as that of Europe is now. It will then be possible, when commercial or other interests may require it, to make not only dwellings but clusters of houses comfortable and ornament them with tropical verdure the year round in the highest northern latitudes. Then may we reasonably expect to have a life-saving service along our coast that will, in connection with the telegraph, make it possible to rescue speedily the shipwrecked, and to snatch from the tops of burning buildings those who would otherwise perish. It is doubtful if the strongest imagination can equal the realities that are to burst upon us in

the not very distant future of electrical appliances, which already surpass the dreams of but a few years since, which are rapidly bringing "the ends of the earth together," and breaking down the barriers that separate nations from the brotherhood a common humanity should lead us to cherish.

The Secretary read a letter from the incoming President, Mr. WILLARD S. POPE, President of the Detroit Bridge Works, as follows:

DETROIT, Mich., Jan. 16.

L. P. Morehouse, Secretary, etc., Chicago:

MY DEAR SIR: I received your kind note announcing my election as President of the Western Society of Engineers. It awakens mingled feelings of pride and pleasure that my friends and fellow members should deem me worthy of their votes for this high office, and regret that the distance of my residence from the headquarters at Chicago renders it impossible that I should give that time and personal attention to the affairs of the Society that would otherwise be both my duty and my pleasure. My shortcomings in this respect will, however, be rendered less serious from the fact that you are provided with two such excellent vice-presidents as my friends Mr. Cregier and Mr. Booth. We read in the copy-book that "vice degrades society," but it must surely be some very different kind of vice from our worthy vice-presidents.

From 1853 to 1866 I lived in Chicago, in the active exercise of our profession. During the last year of my stay our Society was brought into existence. I recall with pleasure several conversations, as to the desirability of such an organization, which I had about that time with some of our honored patriarchs—Colonel Mason, Mr. Chesbrough, Mr. Paine, Mr. Clarke, Mr. Hjortsberg and others. A preliminary meeting was held at the office of Mr. Paine, then Chief Engineer of the Michigan Southern & Northern Indiana Railroad. The pangs of parturition were brief, and the child was then happily born which has since grown into such lusty manhood.

I am a firm believer in the usefulness of such organizations. People devoted to kindred pursuits have naturally much in common, and such a society brings them together, not only professionally but socially. It is the good fortune of our calling that there is not much personal rivalry or competition. The field is so large, and capable of such great subdivision into specialties, that there is room for all; and so the relations of practicing engineers are rarely complicated by personal misunderstandings. At the same time each one, working in his own field (and the working engineer is always a busy man), is rather isolated from his brethren, engaged in differing, but yet kindred pursuits. Such an organization as this brings them together occasionally, and so professional sympathies may ripen into personal and congenial regard and friendship. Doubtless no one goes away from these meetings without feeling that the time has been pleasantly, as well as usefully, spent. But, after all, the great service is probably professional. Here are many bright and eager minds, devoted earnestly and laboriously to the various branches of the broad science of engineering. Each relates his special experience, nothing in which can fail to be of interest to all; and in the conversations and discussions

which follow there is always substantial and suggestive nutriment. No profession is so widely subdivided as ours. In its broad sense it is the *science and art of construction*, and so incloses within its ample limits a multitude of specialties, related and yet differing, connected and yet distinct: and any one of these specialties demands and must receive the best industry and ability of him who would worthily practice it. Rennie built docks, bridges, canals, light-houses, sewers, mills, and undertook mining and metallurgy. At the present day each of these branches has its own disciples and students. One mind cannot grasp so great a field—it is enough to be thorough in one sub-department.

And such a society as ours brings all together, and each one can learn from and profit by his neighbor. Surely its motto might be "E Pluribus Unum."

To be called to the presidency of such a society is an honor to any one, and as such I gratefully accept it.

With best wishes for yourself and the Society, I am, yours truly,

WILLARD S. POPE.

PROCEEDINGS.

FEBRUARY 14, 1882:—The 141st regular meeting was held at 7.30 P. M. No quorum was present and no business was transacted.

L. P. MOREHOUSE, Secretary.

MARCH 7, 1882:—The 142d regular meeting was held at 4 P. M., Vice-President Cregier in the chair.

The minutes of the two preceding meetings were read and approved.

Applications for membership were received from the following-named gentlemen: Charles Ellis Taft, civil engineer, Chicago, indorsed by Messrs. Liljencrantz, Randolph and Powell; Joseph Thompson Dodge, division engineer, Rocky Mountain Division Northern Pacific R. R., Helena, Montana, indorsed by Messrs. Meyendorff, Whittemore and Rust; George M. Garvey, resident engineer, Kansas City, Springfield & Memphis R. R., indorsed by Messrs. Clinton, Wright and Morehouse; Daniel J. Miller, Chicago City Railroad, Chicago, indorsed by Messrs. Weston, Wright and Artingstall.

Messrs. George C. Smith, Henry C. Draper and William H. Lotz were elected Members, and Mr. F. D. H. Lawlor an Associate.

Upon motion by Mr. MacHarg it was voted that a committee of three be appointed to prepare a form of diploma in accordance with Section 6 of Article IV of the By-laws. The Chair appointed as such committee the Committee on Seal, Messrs. Benezette Williams, Morehouse and MacHarg.

Upon motion of Mr. Benezette Williams it was voted that a committee of three be appointed to report upon the best means to secure for the Society portraits of its ex-presidents, Messrs. Mason, Paine, Chesbrough and Sooy Smith. The Chair appointed Messrs. Williams, FitzSimons and Liljencrantz as Committee.

[*Adjourned.*] L. P. MOREHOUSE, Secretary,

APRIL 4, 1882:—The 144th regular meeting was held at 4 P. M., Vice-President Cregier in the chair.

The minutes of the preceding meeting were read and approved. Upon ballot the following-named gentlemen were elected members; J. T. Dodge, Helena, Montana; D. J. Miller, No. 135 Twenty-ninth street, Chicago; George M. Garvey, Springfield, Mo., and Charles E. Taft, Chicago.

Mr. Greeley, for the Committee on Weights and Measures, reported that, owing to their inability to obtain a full meeting, no report had been decided upon.

Mr. MacHarg, for the Committee on Seal, stated that a circular had been sent to each member, and that the Committee hoped there would be a full response.

The Secretary read a letter from Mr. Chesbrough in relation to the memorials upon the death of Mr. Hjortsberg and that of Mr. Lane. No member of either of the memorial committees was present, and no action was taken upon the matter referred to.

Mr. Liljencrantz suggested that the hour for holding the meetings on the third Tuesday be changed, and, upon motion of Col. FitzSimons, it was voted that the hour of meeting for the third Tuesday in each month be changed from 7:30 to 4 P. M.

Mr. Liljencrantz read a paper, "The Best System for Transit Work."

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

ORGANIZED 1880.

TRANSACTIONS.

IMPROVEMENTS IN RAILWAY CONSTRUCTION.

ANNUAL ADDRESS BY PRESIDENT CHARLES PAINE.

[Read March 12, 1881.]

Gentlemen :

Your committee on programme has kindly relieved me from the implied obligation, contained in the constitution of this Club, to prepare an annual address, and has assigned to me the lesser duty of reporting to you such new features as have distinguished railway engineering and practice during the past few years. In order to give time for the more interesting topics intrusted to the gentlemen who are to follow me, I shall be brief. You will realize how little there is which can be new to members, when you reflect upon the fact that every newspaper contains a column devoted to railroad news. You already know that we built in the United States last year more than 6,300 miles of railway, bringing the aggregate up to about 93,000 miles. The so-called capitalists, who print and issue beautiful lithographic bonds and certificates of stock, on account of the new railroads, which they have contracted to have built, by the mile, before the surveys are made, now promise to add to this aggregate a larger number of miles of cheap railways, this year, than in any other year since railways began ; and so to hasten the coming of the usual collapse after a shorter interval of prosperity, as we call it, than we have generally enjoyed. If any one can remember three years ago, he will recollect that he had then very grave doubts whether any of the oldest and best railways would ever pay another dividend ; yet the capitalist does not now hesitate to invest the money of other people in lines alongside of these precarious properties. So much it is necessary to say as to our progress toward the abyss of bankruptcy, which lies at the end of the grade down which we are rushing with all steam on.

Other aspects are more encouraging. Useful and valuable roads are being undertaken in the outlying countries of the globe in all directions. The Territories of the United States, Mexico, Brazil, Japan, Siberia, Australia, Africa, are all to be opened shortly to the beneficent influences of commerce by means of the railroads already projected and in progress. The most important recent change which has affected the railroad interests of the United States is the substitution of the principles of combina-

tion for that of competition in the conduct of their business. Under the wise lead of Mr. A. Fink, a distinguished engineer, the uncertainty of rates, which was so disastrous to shipper, consignee and railroad company, has been replaced by steadiness in rates, and certainty of remunerative returns, without a discoverable increase in the cost of transportation affecting the expenditures of any living person. This certainty of remuneration has emboldened the owners of railway properties to invest largely in the improvement of their roads and their equipment; improvements absolutely necessary to the prosperity of the communities in which they are operated. For although the manufacturer's freight is a valuable contribution to the revenues of the railway, what will he or his customers do if they cannot get cars to move it?

Perhaps the most important economical question of the present season in the United States has been whether or not the necessary additional equipment of cars and engines could or would be provided. The answer would affect every interest of the nation. For seven years the owners of railways dared not invest another dollar in addition to the capital already embarked, for there was no promise of profit or interest. At the end of this period, reviving commerce, manufactures and agriculture found they had outgrown the facilities of transportation, which, during the term of depression, had been largely in excess of the business to be done, and they called upon the railway owners to get ready for the enormous trade they and their customers were now anxious to have developed and transacted. Suppose, then, that pooling, or combination between the trunk lines, had not been effected; that no hope of dividends nor of steady rates could have been entertained by those upon whom the internal commerce of the country depends for the capital to provide it with wheels and to keep them in motion; can any one sufficiently describe the injuries which must have ensued, the delay and hindrance to new enterprises and the resulting effect upon the earnings and profits of every individual in the community? Under the influence of restored dividends, capital has flowed freely into these channels of investment, which had been so long dry: yet those who are familiar with the demand for transportation know how far from filling the want this great expenditure has been.

Among the notable improvements in the operating of railways, which should be mentioned, is the increase which has taken place within a short time in the car load, due almost entirely to engineering improvements in the construction of tracks: better rails, better joints, better drainage, combining to allow one-half more load in the car than it formerly carried. By an increase in the size of the axles and springs, this load has been made double what it was six or seven years ago for the standard freight car. The load per train has been otherwise increased by an addition to the power of the freight locomotive. The so-called *American locomotive*, with four drivers, has been superseded by the Mogul, and that by the consolidated engine, with eight drivers, for freight traffic; European experience having developed a similar effort to make use of so much of the adhesion of the locomotive to the rails as can be availed of consistently with mechanical limitations. The cost per ton hauled depends most upon the number of tons taken per train; the cost per train being in comparison but little affected by its size.

I have already referred to the improvements in track, of which the general substitution of steel rails for iron has been the most important. Certainly, if it had not been for Mr. Bessemer's discoveries and inventions. the present railway and its traffic would have been impossible; and, although Mr. Bessemer gave us steel rails, he could not tell us, nor could any one, until experience had been had, how to make the best steel rails. The liberal and scientific minds which conduct the Pennsylvania Railroad have, through their experts, given us a nearer solution of this most important problem than we have ever had, and they have lately nearly demonstrated the correctness of their conclusions. I refer you to Dr. Charles B. Dudley's paper on "The Wearing Power of Steel Rails in Relation to their Chemical Composition and Physical Properties," reprinted in the *Railroad Gazette*, February 11, 1881, and in the *American Engineer* as a model of what an engineer's paper should be, and also as the most important contribution to our knowledge of the chemical structure of the rails which has yet been made.

Not long ago, much anxiety was felt as to a supply of timber for ties being obtainable. The cause for anxiety has been removed in three ways: First, by a demonstration that we can prolong the life of our perishable timbers by creosoting and other processes, so as to make them available (an excellently well designed apparatus on wheels, which has been used in France for this purpose, lately appeared in *Engineering*); second, by showing that we can grow the ties of durable timber rapidly enough on waste lands, whenever we will arrange to do so; and thirdly, by the showing already made in Germany and in England that a track with iron sleepers is probably better and more durable than any other. Some trifling improvements in fastenings of the rails to the sleepers, which the celebrated Yankee baby is now pondering in his cradle, are all that seems necessary to make the iron way a *permanent* way indeed. The mileage of cast-iron wheels has been increased—it has about doubled—on the average during the past eight years, although the load upon the wheels has increased also. Responsible makers now guarantee the wheels under passenger cars and locomotives to run at least 60,000 miles. The metre gauge, adopted for the Government railways in India, appears at last accounts to have been abandoned, the main lines now in construction being made of uniform gauge with the older lines.

Attempts at improving the locomotive in other ways than I have mentioned are not wanting. The principle of the compound engine has been experimented with, one cylinder using the steam at its highest pressure and passing it over to a larger one to be used to its extremest expansion. The arrangement has been found economical of fuel, but its use upon fast trains or heavy trains has not been shown to be practicable. In a locomotive we must have the most rapid and efficient development of power at whatever cost. We cannot wait to save fuel if we can go faster by burning more of it. Mr. Wootten has had the courage to make his fire-box big enough to burn poor fuel, or good fuel somewhat more slowly, and an economy is hoped for by this means. I cannot yet say that it is assured. Mr. Fontaine has attempted a high-speed locomotive by mounting one pair of drivers over the other pair to propel

them by friction; he can doubtless run fast without a load; to draw a load he must have adhesion: to have enough adhesion he must concentrate the load carried by the four drivers of ordinary locomotives upon his two, which is fatal to his scheme, as I believe.

A brave man in Europe, Mr. Verderber, has made the fire-box of his locomotive of fire-brick, surrendering the use of the end and sides of the fire-box as heating surfaces; yet, contrary to the predictions of his comrades, he has obtained about as rapid generation of steam, from a given quantity of fuel, as with the ordinary fire-box. Whether he will attain any economy or other advantage is not yet shown; but the result which I have mentioned is likely to have a great effect upon boiler constructionin the future.

Signaling has been much improved here and abroad. The interlocking of switches and signals is coming more and more into use on busy lines. An hydraulic system of interlocking and operating the switches has lately been introduced, from which I anticipate the most excellent results, judging by the success which has attended all previous uses of hydraulic power. The block system, insuring a positive space between trains, is gaining new friends with every rear collision. The telephone is the greatest convenience ever introduced into the large freight yards.

An electric railway has been put into service at Berlin, with promise of some success for light trains; and with the rapid development in the art of producing electricity we hope for an important addition to our means of transportation in cities from its employment. I have not been able to find a description of this railway, sufficient to give clear ideas of it, although I think one has appeared in *Engineering*.

In looking over some statistics of mileage, it impressed me as a fact indicating a creditable advance in the railroad art, that a single postal car running between New York and Chicago had made trips amounting to 482 miles per day, continuously for two years, or a little more than twenty miles per hour during the whole of that period. Other cars had done a little more than this in the last year, but this one had followed it up for two years, and is still going.

It is gratifying to be able to report some improvement in legislation concerning railways. The better sense of the people has triumphed over the granger foolishness, and admits that it is safer to have the roads prosperous, so that they can be maintained in good condition, rather than to have them starved into an economy, which will compel them to neglect the renewals upon which safety depends. In several of the States, the Railway Commissioners have been of great service in bringing about this return to reason; acting, as they have, in a judicial capacity, and deciding justly between the clamors of popular prejudices, on the one hand, and the partial views of railroad managers on the other. Yet the tendency of railway legislation continues toward the impracticable: attempting to fix invariable tariffs of rates (affecting the commerce of a whole continent), rather than to the perfection of the laws, which will contribute to speed, safety and comfort at home: an object of much more importance to the community and within easier reach of the understanding of those who are called to make our laws. I believe a commission of ordinary legislators appointed to inquire what could be done to improve matters in this respect would evolve considerable im-

provements, especially if they were to ask for suggestions from persons familiar with the subject. Consider that the thousands who ride on trains through the State of Ohio are without protection from being upset at any highway crossing, or private crossing by the flocks and herds of any honest or dishonest agriculturist, who chooses to let his animals stray on to the railroad track! In a civilized country like France, for instance, it is a penal offense to have allowed an animal to get upon the railroad; and whether the railway fences are in good order or not, the innocent passengers upon the trains are not to be imperiled by the neglect of the railway or of the owner of the animal. Whoever owns an animal in that country must see to it that it cannot cause injury to others. But an animal is a slight obstruction on the track in Ohio; more dangerous objects, like a saw-log, a safe, a house or barn are frequently discovered by the locomotive engineer directly in his path. The Supreme Court of Indiana decided that under the laws of that State a drove of mules had the same right to the crossing as the locomotive of the express train.

Let me give another illustration of the need of the most obvious legislation. On one railroad with which I am acquainted about 100 persons are run over every year, for the reason that they prefer to walk upon the track rather than upon the highway. It is not in the power of the railroad company to protect these persons; they are a source of danger, annoyance and expense to the railroad; but it has no remedy—yet a remedy is in the hands of the legislature.

Again, if you were to be asked, as a body of engineers, to make the most complete arrangements possible for the production of railroad accidents, would you not require all railroads to cross each other at grade? That is in substance the law of Ohio, and of most of the Western States. It is not conditioned upon the difficulty or expense or impossibility of making an over or under crossing; only upon the will of the projected line, as to where it shall cross another; and in several instances, which have been reported to me, the crossings so chosen were at places which involved great danger and injury to the older road, and could have been made over or under by the proper location of the new line.

It has seemed to me appropriate, after reciting the improvements which have been effected in the art of *railroading*, to point out the most important defect of the railroad system of America. Mechanically, economically and in administration our roads are well abreast of the railways of other countries, so far as one may judge from the technical journals; but we suffer from a neglect of fostering legislation, and from the omission by our legislators to provide for the safety of those who travel upon the railroads. The aim here has been to limit the powers of the corporations; that is well enough, they should be limited to the complete and perfect execution of the duties for which the corporations were created; but it ought to be now perceived of what importance to the community this new instrument of commerce and of circulation has become; that every individual is interested to have the promptest, safest and most rapid movement of trains which is possible; and to that end the study of those who make the law should also be directed. Without this, American railroading must continue as it has been heretofore, unsafe, from causes beyond the control of those who operate the roads.

CRYSTALLIZATION OF IRON.

By N. P. Bowler, Member of the Club.

[Read December 13, 1881.]

In what I shall have to say to-night about the crystallization of iron it must not be expected that I shall go over much, if any, of the ground traveled by writers on this subject in the text-books, as these experiments are familiar to you all. But I only propose to give such facts as have come to my knowledge in the course of my experience in carrying on the business of a foundryman, and such as I have gathered from the experience of others in similar pursuits.

Our practice has been to watch closely the safe condition of all the tools and appliances used by our men about the foundry, both as a humane measure, as well as in a financial point of view, to avoid accidents to any of the employés.

The theory that pieces of wrought iron or steel will crystallize by merely hanging for a certain length of time in a vertical position seems to be confirmed as true in this instance.

We had a chain in daily use in our foundry—used for raising flasks and castings—requiring it to hang in a vertical position most of the time. It had been in use probably 8 or 10 years. The links were of about ½-inch wire, as you can see by this piece of it. The service usually required was light compared with the ability of the chain. One day a link broke squarely off. The chain was sent to the blacksmith shop for repairs. The smith called my attention to the fact that if he put any of the links on end upon the anvil a light blow of the hammer would break them into four pieces. He tried several of them and they broke as easily as poor cast iron. I asked him to put a link in the fire, heat it to a red heat and let it cool gradually. He did so and found it would not break then, but bend like good iron. I had the chain mended, and after emptying one of our large ladles of the molten iron, thus leaving it red hot, the chain was put into it to remain all night. That was done over three years ago. The chain has been in constant use ever since with no signs of weakness by crystallizing.

We served all our chains the same way by heating them, and cooling gradually, and have had no recurrence of this kind. I would recommend that the ladle shanks used about the foundry be treated the same way.

A very interesting fact was related to me not long since by a division master mechanic of the Lake Shore & Michigan Southern Railway. He had just made two fire boxes for a couple of his engines, from steel plate or homogeneous iron. They were completed, and the engines were ready to run; steam had been got up in both, and found all right.

The following day the fireman of one was told to fire up his engine, the same as he had fired the day before. After starting a pretty good fire, and seeing no signs of steam, he ran horror-stricken to tell his engineer that there was not a drop of water in the boiler, and that everything was red hot. The master mechanic, who happened to be there, quieted his fears by telling him to "never mind—just pull your fire and let the engine stand and cool off."

That was, I think he told me, ten years ago, and that fire-box has been

in use all the time, and is good to-day; while its mate, made of the same material, lasted but a few years before it cracked and became useless.

Although that fire-box was not crystallized by using, yet is it not more than probable that the same conditions existed in this metal that we find in iron and steel that have become brittle by long usage—it becomes what is called crystallized?

There is no doubt that car axles become crystallized by long usage; but the time it takes to reach that point—when they are entirely unsafe to use—varies undoubtedly according to the good or bad quality of the iron. Some kinds of iron are brittle, and will soon fail, while others are of softer and more tenacious fibre, and require a longer time to crystallize.

The above facts suggest to me the feasibility and utility of converting old car axles into good ones, by merely annealing them.

It is the practice of master-mechanics of railroads to condemn axles that have been in service a certain number of years, if for no other reason than that of being crystallized, acting on the theory that such an axle is unsafe for further use.

They are taken out and cast into the scrap pile to be sold to the junk dealers for about one-third the price of new ones.

Some master mechanics that I know do practice the annealing of old axles, but by the number known to be for sale as scrap, one would think but very few did so.

The practice now is to increase the capacity of freight cars from what they were formerly—ten and twelve tons—to fifteen and twenty tons, thus making it necessary to take out the small axles; but when confidence can be put in these annealed ones, there will be no objection to using in narrow-gauge cars axles once under standard-gauge cars.

The crystallization of cast iron to such an extent as to make it unsafe for further use is still a mooted question. Railroad men in the early history of that enterprise, before the use of fish plates—believed that the car wheel, by striking the head of the rail would become crystallized—and were disposed to remove all wheels from under passenger coaches, after having been in service a certain length of time, to be worn out under freight cars. What the length of time is, beyond which it was considered unsafe to run them, was never definitely settled. I think the practice has quite gone out of use, and the belief that chilled car wheels will crystallize by running so as to become unsafe is not very generally entertained.

Old car wheels are used to some extent in the mixture of iron for new ones.

I have, for a period of sixteen years, watched the appearance of those old wheels, as they were broken up, and I have been unable to notice any difference that could be charged to the time in service. We sometimes find wheels that have been made twenty years—of course, the amount of service they had done could not be known. Wheels ten years old are quite common, but that time had wrought changes in the metal was not perceptible by any means that I possessed.

And my belief is that car wheels, at least, do not grow weaker as they grow older by reason of crystallization. It was but recently we had at the foundry some old cast shafting, and I noticed it particularly when

broken up for the cupola, that there was no appearance of change in the metal, either by breaking or in looks, to indicate crystallization.

DISCUSSION.

[In the after discussion of his paper, Mr. Bowler stated that he did not believe cast iron subject to crystallization; that during his long experience in the manufacture of car wheels, where large numbers are broken up, he had never seen a case of crystallization among them.

He thought car axles might be so affected and that wrought iron is more subject to it when used in a vertical position.

Mr. DUNHAM: Was not your chain subjected to unequal strains by passing over a pulley?

Mr. BOWLER: It did not pass over a pulley.

Mr. BIDWELL cited a case at the Chickering Piano-Works, where a vertical chain had broken from crystallization, without apparent cause, except what might be due to its vertical position.

Mr. RENSCHEL, of the Cleveland Bridge and Car-Works, thought that iron never crystallized unless overstrained. He thought that car axles are being constantly overstrained by a force that cannot well be estimated: the passing of the wheels over rail heads was but a succession of blows that result in overstrain, and crystallization follows.

Col. WILSON, of the United States Harbor Improvement, mentioned the fact that he recently condemned a number of tons of bolts and spikes before being used, because they were crystallized. They could not have been overstrained.

Mr. RENSCHEL: They were doubtless made from very poor iron at first.

Mr. BIDWELL thought cold-drawn wire a good example of overstraining that does not produce crystallization.

Mr. PORTER, of the King Bridge Works, stated that the experiments conducted by the United States Government went to show that no crystallization takes place where iron is not strained beyond one-half its elastic limit.

Mr. LATIMER, Chief Engineer of the N. Y., P. & O. R. R., said that the question was once asked at a meeting of his roadmasters: "Is it not a fact that iron lasts longer, that it will sustain more wear, by allowing it to rest one day in seven?" The answer was not given.

The further discussion of the subject went over to the next meeting, on a question by Rev. Dr. Brown as to the chemical signification of crystallization, which was referred to N. B. Wood, analytical chemist, for answer.]

PROCEEDINGS.

FEBRUARY 14, 1882:—Regular meeting, Vice-Pres. Col. J. M. Wilson in the chair.

Minutes of previous meeting read and approved.

The names of S. T. Wellman, C. E. Burke and C. B. Krause, were nominated for active membership, and laid over one month under the rules. The Secretary was requested to cast the favorable ballot of the club electing W. H. Phillips and Henry Wood to active membership.

The Secretary then read a communication from Chas. H. Haswell, presenting

the Club with a brick taken from the house, in New York, known as Washington's headquarters, the brick having been imported from Holland during the last century.

The Secretary was instructed to send the thanks of the Club to Mr. Haswell, for his kindly and valuable souvenir.

The Chair appointed the following gentlemen as a committee to nominate officers for the ensuing year, with a request to report during the evening: G. A. Hyde, C. P. Leland, J. F. Halloway, J. N. Richardson and J. L. Culley.

Mr. J. F. Halloway presented the following resolution:

"*Resolved*, That in view of the recent death of the eminent and widely known engineer, Alexander L. Holley, a committee of three be appointed by the Chair for the purpose of presenting resolutions expressive of the loss which we, in common with the engineers of this country, have sustained by the death of so valued and honored a member of our profession."

Messrs. J. F. Halloway, Chas. Latimer and J. D. Crehore were appointed such committee.

Mr. M. E. Rawson then read a paper entitled "A History of Cleveland Pavements." The subject was discussed by Messrs. Claflin and Latimer. The latter exhibited a hexagonal masquit paving block from Texas.

The chair announced the names of Messrs. J. F. Halloway and J. A. Bidwell as two of the members of the committee of three to memorialize Congress to continue the tests of iron, steel, etc.

The Committee on Nomination of Officers, to be voted on at the annual meeting in March, made its report, which, after some changes, resulted as follows: For President, Col. J. M. Wilson; for Vice-President, J. F. Halloway; for Corresponding Secretary, Prof. A. L. Airey; for Recording Secretary, M. W. Kingsley; for Treasurer, J. S. Oviatt.

The committee appointed to present resolutions upon the death of Alexander L. Holley presented the following report, through Mr. Latimer, which was prefaced by a most eloquent and touching address by the chairman of the committee, Mr. Halloway, who had had an intimate acquaintance with the deceased.

Resolved, That the members of the Civil Engineer's Club of Cleveland have heard of the death of Alexander L. Holley with profound sorrow and regret.

Resolved, That in the death of Mr. Holley the engineering profession of the world has lost one who not only contributed largely to the success of all industries connected in any way with metallurgy, being the father, as it were, of the Bessemer steel process in this country, but also added largely to the high order of our literature.

Resolved, That while he held a position among the highest of our profession, he will ever be remembered and mourned on account of his great personal worth and purity of character.

On motion, the resolutions were unanimously adopted.

On motion, the Secretary was requested to convey to the family of the late Theodore R. Scowden and to the press a copy of the memorial upon his death, adopted by the Club at its last meeting. Also to express the regret that the public announcement of the funeral had not been such that the members of the Club would have felt at liberty to have attended the funeral in a body.

On motion of Mr. Leland, it was decided that the annual meeting, to be held Saturday, March 11, 1882, should be considered in lieu of the regular meeting to be held on the Tuesday following and that the latter be indefinitely postponed.

On motion, a vote of thanks was tendered to the gentlemen who had contributed to the evening's entertainment, after which the Club adjourned to meet Saturday evening, March 11, 1882.

C. H. Burgess, Recording Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. I. APRIL, 1882. No. 6.

This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

A THEOREM OF STATICS, WITH SOME GRAPHICAL APPLICATIONS.

BY CHAS. A. SMITH, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read April 20, 1882.]

When four forces are in equilibrium, the resultant of one pair must balance the resultant of the other pair.

In the general case, the four forces do not act at one point, and there is only one solution.

The construction herein given I have not met with, and as it is useful in applications to frames and trusses, I have given some examples of its use.

APPLICATIONS.

When four forces act upon a body and are in equilibrium, if one force is known in position and magnitude, and the lines of action of the other three are given, to find the magnitudes of the three others.

Two cases occur obviously. The first, or general case, where the four given lines of action do not meet in one point: the second, or special, where they do so meet.

In Fig. 1, let P be the given force, and let R_1 R_2 and R_3 be the forces whose lines of action are given and whose magnitudes are sought. Since the body is equilibrated, the resultant of any one pair must be equal and opposed to the resultant of the other pair.

Let R_1 and P meet in A, and R_2 and R_3 at B, then must the resultant of R_1 and P, acting through A, have the direction $A\ B$ and act through B, because in no other way can it balance the resultant of R_2 and R_3. The position of the resultants at A and B being determined, a triangle of equilibrium may be drawn for the point A from the known value of P as on one side, and then a triangle of equilibrium for the point B with the found value of the common resultant for the known side.

The construction given above is peculiarly advantageous when taken in connection with Rankine's "Method of Sections" for frames and

trusses and with Maxwell's "Method of Reciprocal Figures," and although these are well known in certain applications to Rankine's "Method of Polygons," yet in other equally well described applications their use is by no means universal, and I venture to add solutions of two problems.

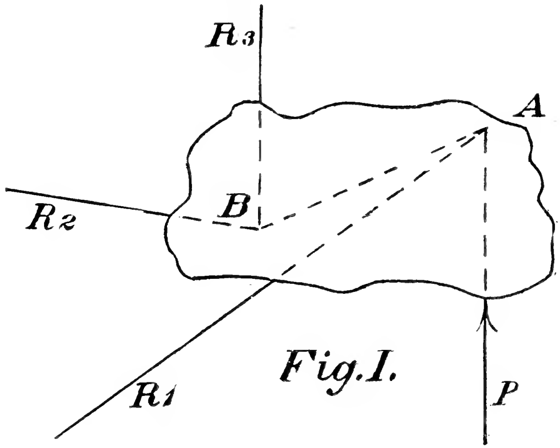


Fig. I.

PROBLEM.

1. *Given*, Any number of forces in one plane in direction and magnitude to find their resultant.

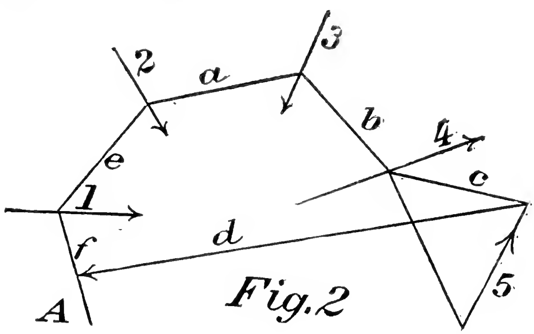


Fig. 2

Let, in Fig. 2, Nos. 1, 2, 3, 4 and 5 be the given forces. Then, at any point in the line of action of one of the forces, as No. 3, if we equilibrate it by two forces, as *a* and *b*, we find the magnitudes of *a* and *b* by drawing to scale a triangle with sides parallel to 3, *a* and *b*. This triangle of equilibrium is shown in Fig. 3. Now, if at the point where *b* cuts 4, we apply a force equal and opposite to *b* and another force *c*, we can hold 4 in equilibrium: *c* is determined completely by 3 and 4, and is shown and found by a triangle of equilibrium in Fig. 3.

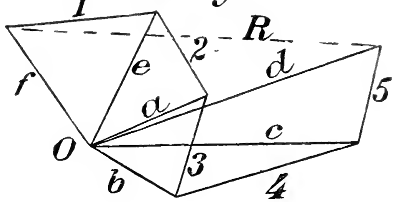
We have now the forces *a* and *c* balancing 3 and 4, and in the same way we find a third force *d*, which, taken with the equal and opposite of *c*, balances 5, and is shown and found in Fig. 3. In like manner are found *e* and *f*, and lastly, the resultant of *f* and *d*, which two forces balance the entire given system, and which, therefore, must be equal and opposite the required resultant of the given system.

This resultant acts through A, where f and d meet in Fig. 2, and is completely determined in magnitude and direction by R of Fig. 3.

The solution is then briefly effected as follows :

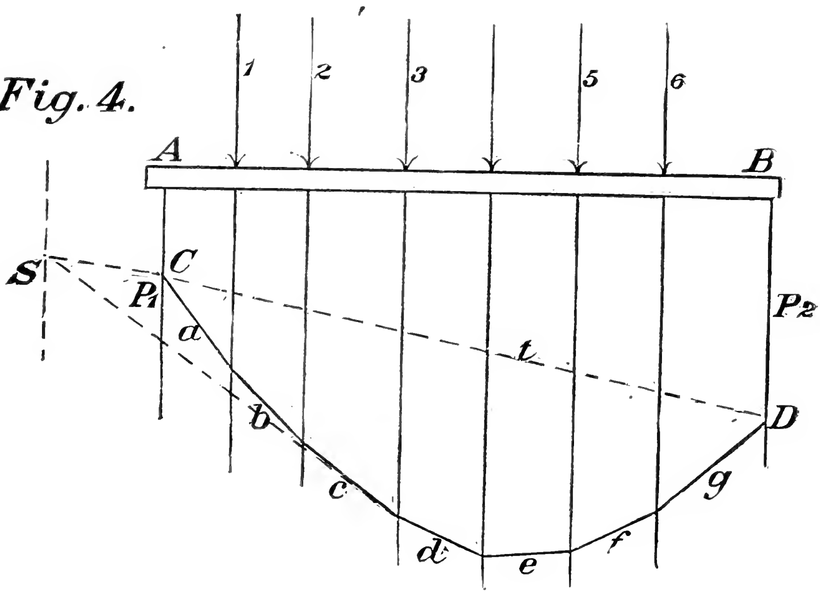
Draw lines parallel to the given forces taken in order, with lengths proportioned to the forces, thus forming an open polygon, as 1, 2, 3, 4 and 5 in Fig. 3. From any point o draw radiating lines to the angles of this polygon, one more in number than there are sides thereof. Next construct a polygon with sides parallel to these radial lines, and with angles on the lines of action of the given forces, as a, b, c, d, e and f in Fig. 2. The point where the first and last of these lines meet A is in the line of action of the resultant, and its magnitude and direction are given by the side R required to close the force polygon in Fig. 3, acting, however in the reverse direction : for if the force polygon is closed by R, we must have all the given forces and R in equilibrium.

Fig. 3.



If the given forces had been in equilibrium among themselves, the force polygon of Fig. 3 would have closed, and we should have had only

Fig. 4.



as many radial lines as we had sides, therefore, there being no resultant, the first and last sides of the polygon in Fig. 2 must have coincided in one.

Corollary. The resultant of any group of adjacent forces may be easily

found by producing the inclosing sides of Fig. 2 and joining the angles of Fig. 3.

When the forces are in equilibrium, we at once see the "Reciprocal Figures," for the lines making a closed polygon in one figure are represented by lines radiating from a point in the other.

PROBLEM.

2. The positions and magnitudes of the loads on a girder being given, to find the vertical abutment reactions.

Let, in Fig. 4, AB be the girder, and let 1—6 be the vertical loads, to find the supporting forces P_1 and P_2.

Draw verticals through the lines of action of the forces in Fig. 4, and draw the open-load polygon EF in Fig. 5. The six sides all lie in one straight line. From any point o draw radiating lines to the line of loads, and draw the open polygon *abcdefg* in Fig. 4 with angles on the vertical lines of action. The whole effect of the six loads may now be considered as balanced by a and b, but a and b intersect P_1 and P_2, and, as the loads are to be carried by P_1 and P_2, the resultant of g and P_2, must balance that of a and P_1, acting on the line CD: draw then t in Fig. 5 parallel to t in Fig. 4, then will GE represent P_1 and FG represent P_2.

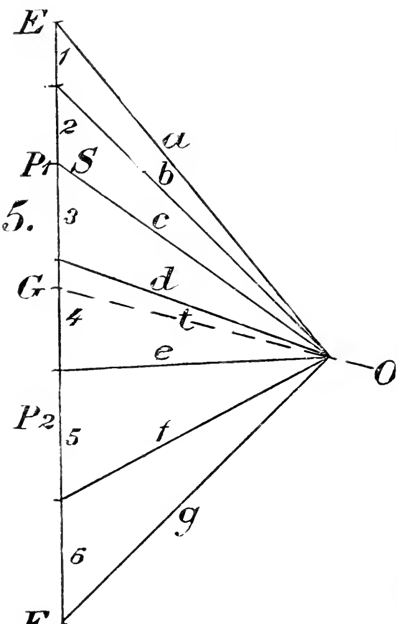


Fig. 5.

We may note that the final condition of equilibrium in Fig. 4 is represented by the closed polygon in Fig. 5, 1, 2, 3, 4, 5, 6, FG and GE, while the lines radiating from O, a, b, c, d, e, f, g and t form the closed polygon of the other figure.

Corollary. The resultant of, say, P_1, 1 and 2 is at S, where t and c meet, and its magnitude is GS, acting upwards, for GE, 1 and 2 leave SG to be closed in the load polygon, and the lines t, a, b and c from o form the closed polygon a b c and t in the other figure.

Rankine's "Method of Sections" is briefly as follows, for forces in one plane: If any frame is in equilibrium under external forces, then if an ideal section be made passing through the frame, then must the external forces on one side of the section be balanced by the reaction of the bars cut by the section, and, furthermore, if such section cuts not more than three bars, the reactions of the bars may always be determined; if more than three bars are cut, the problem is indeterminate.

Now the external forces on one side of the section have generally a single resultant, found easily and graphically by the "Method of Reciprocal Figures" just given, and that resultant and the reactions of the three bars cut by the section are the four forces of our first proposition. I give three examples of practical use.

Fig. 6 gives a frame rafter supported by a roller on the right end and loaded with oblique forces, 1 and 2 being resultants of load and wind,

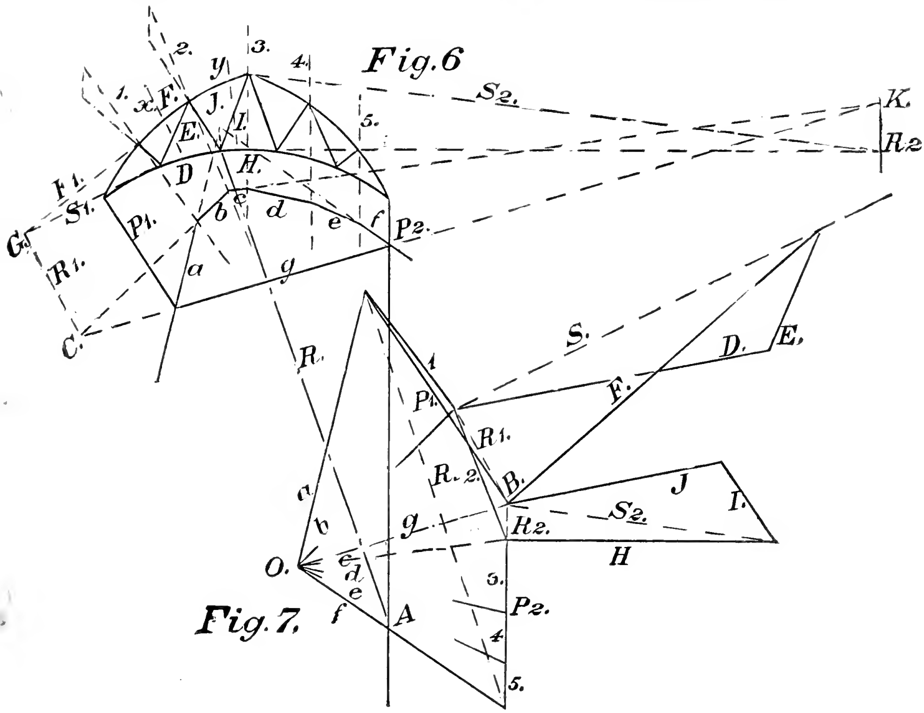


Fig. 6

Fig. 7.

while 3, 4 and 5 are vertical loads. In Fig. 7 the open-load polygon 1—5 is given. The radial lines *a*—*f* from pole *o* are shown and the open polygon of Fig. 6. *a*—*f* is drawn and *a* and *f* produced to meet in the line of the single resultant of loads 1—6. This resultant, *R*, meets P_2 in *A*, and the line of action of P_1 must pass through this point, whence, by drawing parallels in Fig. 7, we have the value of P_1 and P_2. (The values of P_1 and P_2 may be easily found by resolving *R* into two components, one of which passes through the only point known to be in the line of action of P_1, viz., the left abutment, and the other meets the vertical through the right abutment or line of action of P_2. These two components and the two reactions P_1 and P_2 are then the four forces of our theorem, and P_1 and P_2 are at once found. Note the horizontal line through the ends of the rafter can be taken for the line of the two common resultants.) Draw *g* from *o* to *B* in Fig. 7, and draw *g* parallel in Fig. 6, completing the "Reciprocal Polygon."

We are now ready to examine any part of the rafter. Suppose we take the section between 1 and 2 dotted at x. The line in Fig. 7 from B, marked R_1, is the resultant of P_1 and 1, and is applied at C, Fig. 6, where b and g meet. To find the stresses on the bars D, E and F, R_1 being known, we have now the four forces of the theorem. Producing D and R_1 and drawing S from their intersection to the intersection of E and F, we draw in Fig. 7 the triangle of forces R_1, S and F for the equilibrium at G, Fig. 6, and then drawing the triangle S_1 D and E for the other point we have the stresses in D, E and F found. Passing to another section dotted at y between 2 and 3, we have R_2, the resultant applied where c and g meet at K. The bars H, I, J and force R_2 are the forces of the theorem, and the forces H, I and J are found in the same way and drawn in Fig. 7. Further application is readily made.

Fig. 8 is for a truss bridge, and the investigation is confined to the action of the bracing under traveling load only. It is well known that the worst load on the brace in any panel is when the load extends from either abutment to that panel, the action being tension if the brace slopes up from the load and compression if it rises toward the load. The live load is supposed to be headed by a panel load 50 per cent. heavier than those which follow it and to come from the left. In this case it is easier to find the abutment reactions by drawing a reciprocal polygon for each case of loading than to compute them. The five reciprocal polygons for the five cases of loading are drawn one under the other, and also the five load polygons, though the latter would in practice be merged in one. The abutment reactions are then found. As the plane of section is taken in front of the loads, there are no loads between the plane of section and the right abutment; by taking the right abutment reaction we have the single force always applied at the same place.

For each case of load two planes of section are used, one for each brace in the panel. The lower bar being horizontal, its intersection with the abutment reaction remains at the same point, and the common resultant lines S are drawn therefrom to the joints of the upper chord. For the two planes of section, the line S remains the same for each case of loading, and the forces on both braces are drawn for the common value of S.

In Fig. 9 is given the complete graphical solution for a girder, the dead and total load forces being found by the ordinary "Maxwell Diagram," while the live load forces are found by the method here given.

THE BEST SYSTEM FOR TRANSIT WORK.

By G. A. M. Liljencrantz, C. E., Member of the Western Society of Engineers.

[Read March 4, 1882.]

It is well known that different surveyors employ different systems for keeping their field notes, not only in leveling, but in general transit work as well.

It will probably be admitted, however, that it would be better in many instances if one common system could be universally adopted for the field notes of either class of work. Assuming this idea to be accepted, it

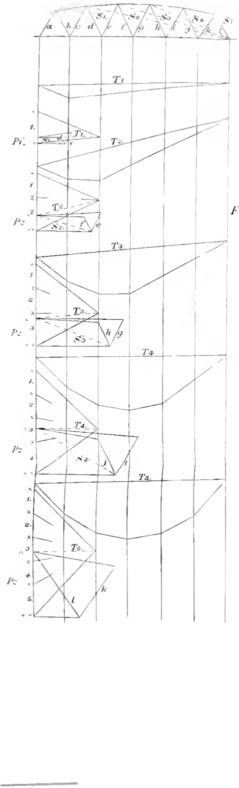
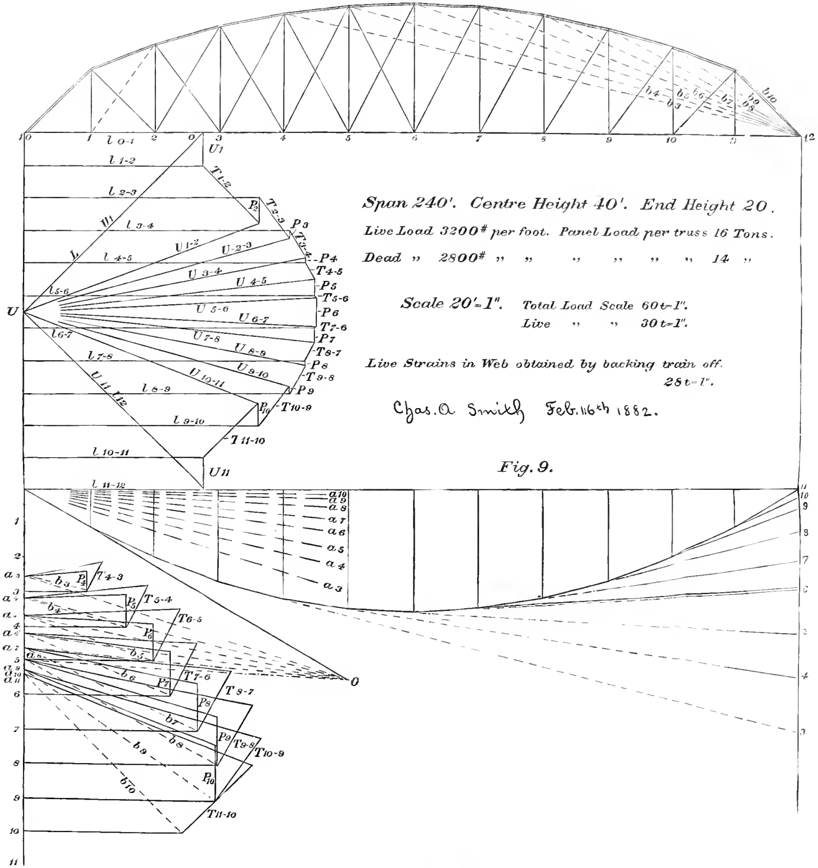


Fig. 8.



Span 240'. Centre Height 40'. End Height 20.
Live Load 3200# per foot. Panel Load per truss 16 Tons.
Dead " 2800# " " " " " " 14 "
Scale 20'=1". Total Load Scale 60t=1".
Live " " 30t=1".
Live Strains in Web obtained by backing train off. 28t=1".
Chas. A Smith Feb. 16th 1882.

Fig. 9.

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remains to select some certain one as a standard, which may prove itself in simplicity and other governing features preferable to others.

For general transit surveying there is one system which the writer regards as entitled to this preference, and the purpose of this paper is an attempt to justify this opinion.

It is but natural that, to any surveyor, *that* particular system by which he has become accustomed to do his work appears to him to be the simplest and most convenient; but to be a fair, unprejudiced and competent judge between the merits of different methods, one should be well familiar with each.

If we ignore all details of minor importance, wherein the notes of one surveyor may differ from those of another, we find one feature which is distinctly characteristic of the methods most commonly in vogue, especially among railroad engineers, if I am not mistaken, and that is the manner of designating the observed horizontal angles, with reference to the quadrants to which such angles belong.

Four different directions from any one certain point may thus be designated by the same angle *numerically*, and the points of the compass must be resorted to in addition, to sufficiently define one certain course, as, for example, N. 10° 30′ E., S. 10° 30′ E., etc.

Let us, for convenience sake, in the following, call all systems based on this principle with one common name, "*Quadrant system*;" and let the "*Full Circle system*" indicate the one which has been alluded to above as deserving the preference.

The most essential difference between these systems lies in the manner of designating the bearings of lines and sights involved in the survey, and the names suggested above are intended to point out the difference. Any bearing is, according to the *full circle system*, definitely described by one angle, expressed in degrees and fractions thereof, and having reference to one certain course, generally the true or magnetic north.

The quadrant systems are certainly simple and easy enough to understand; but in practical use there will be found in them many drawbacks and many chances for errors, which in the full circle system are not met with. This statement is equally applicable to the field work and to the subsequent work of preparing and plotting the notes in the office, and I shall always keep in grateful remembrance Mr. W. H. Hearding, Assistant Engineer in the United States Engineer Office in Milwaukee, who, in 1872, called my attention to, and kindly instructed me in the peculiarities and advantages of this system. These are probably already known to many; in fact I had long supposed myself to be one among the few that had remained ignorant of this system; but having in latter years frequently met surveyors who were entire strangers to the same, I have concluded that it may not be as generally known as I had at first imagined, and I have therefore thought it desirable to make available to others the information which has proved so beneficial to me.

The subject may be divided into three parts, in which we will separately consider:

1st. The instrument.

2d. The field work, and

3d. The office work.

1. *The Instrument.*

Any transit or theodolite may be used, provided that its horizontal circle is divided and marked from right to left (or as the figures on the dial of a clock) from zero to 360°, with subdivisions as usual: further, that it has two verniers, placed diametrically opposite each other, and, last, that it is provided with a good magnetic needle of fair size.

All angles are counted from zero without any reference to whether they belong to the first or any other quadrant, and in most all cases *both* the verniers should be read and the results noted, the α—vernier (to the right of the line of sight) first, as this gives directly the deflection from the plane of reference, and the β reading next, which represents the *directly opposite* direction to the former, or, in other words, is $= \alpha \pm 180°$.

If α is less than 180°, then $\beta = \alpha + 180$, but when α is larger than 180, then $\beta = \alpha - 180°$.

It is now evident that an α—reading of, say 40°, with zero on the true north, is identical with the course N. 40° E.; 140° is the same as S. 40° E. (180°—40°=140°); 220°=S. 40° W. (180° + 402=20°), and so on.

The fact that the α and β readings represent *directly opposite* directions, as shown above, is one of the fundamental principles for the operations under the "full circle system," and should therefore always be borne in mind, although it is a matter of fact which may at first appear as not worthy of special notice.

2. *The Field Work.*

In considering the field work, let us assume that we are about to run a transit line.

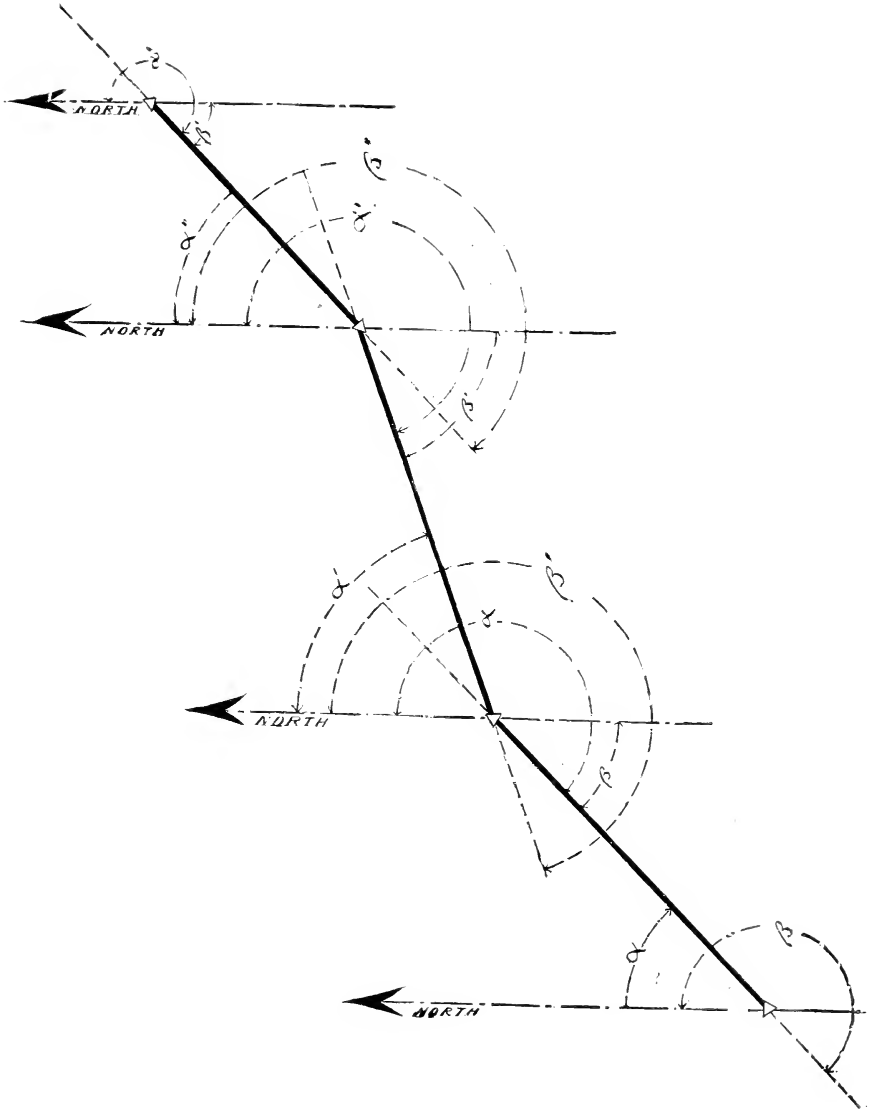
A certain course must be adopted as the base, from which all horizontal angles are counted during the progress of the survey. The true or magnetic north is the most convenient, but any course *may* be used for that purpose (just as in making a drawing, any line may be chosen on which to complete a desired construction), provided that its true or magnetic course is, or can be later on, determined.

After the instrument has been properly placed over the first hub and leveled up, clamp the upper limb with the α—vernier on zero; then turn the instrument, the lower limb being loose, until the telescope is directed in the course adopted as that of reference. Let us in the following assume that the magnetic north is chosen: then the instrument should be turned until the needle points exactly to zero. Clamp the lower limb. In this case, it is evidently necessary that this instrument station is so selected that the needle is not affected by any surrounding objects.

The instrument is now properly set, the upper limb may be loosened and sights taken in any direction, each reading—between 0° and 360°—being counted from the adopted base.

For the sake of being systematical, the first observation at every hub—after the instrument has been properly set—should be that to the next following one, *i. e.*, in direction of the next base of the transit line, and, to avoid confusion, separate columns in the field-book should be devoted exclusively to these angles, one for the α and one for the β readings. When all work at this station is completed, move to the next hub and proceed as follows:

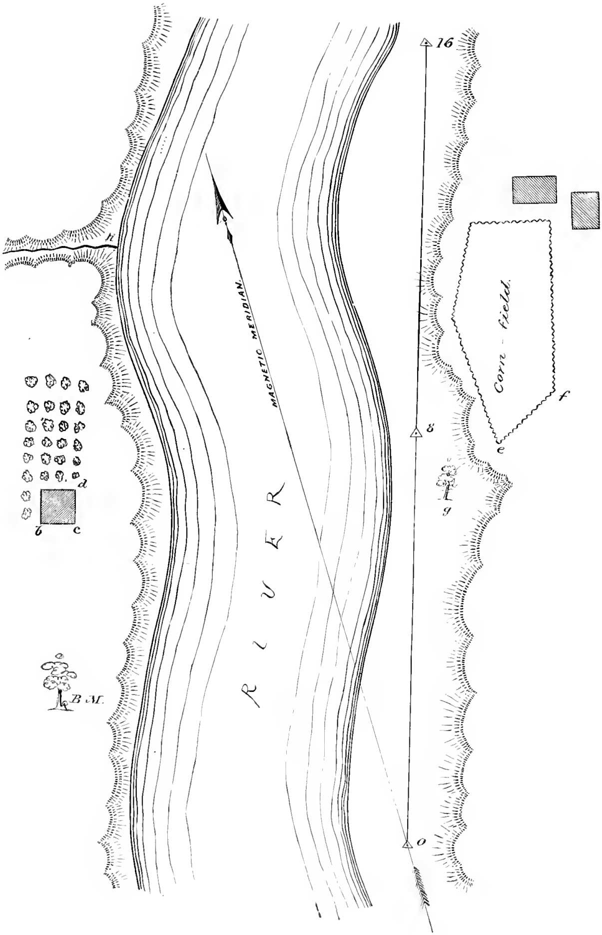
Clamp the upper limb so that the β reading, as observed at station zero to this hub becomes the α—reading here, then turn the instrument to station zero and clamp the lower limb. It will be clearly seen that



the instrument has now the same position, relative to the meridian, as it had at the previous station. To prove this, and ascertain that no error is made, unclamp the upper limb and revolve until the α—vernier reads zero, when, if the instrument has the correct position, the needle

SAMPLE PAGE.—NOTES.

STATION.	α	β	Needle.	Miscellaneous.	REMARKS.
	14° 18′ 30″	194° 18′ 30″	......	....	....
16......................... △			○	....	....
15............	228° 15′ 00″	48° 15′ 00″	*g*	150° 16′ 30″	Tree.
14................	....	....	*f*	104° 6′	Cor. fence.
13.......	....	....	*e*	110° 51′ 30″	Cor. fence.
12	... .	....	*d*	239° 54′	.. ..
11...................	....	....	*c*	238° 27′	....
10.........	....	....	*b*	———	Can't see.
9...	48° 15′ 00″	228° 15′ 00″	*a*	231° 15′ 30″	B. M.
8... .... △	△	△	○	....	....
7...................	211° 17′ 30″	31° 17′ 30″	*g*	42° 8′ 30″	Tree.
6......	....	....	*f*	47° 43′	Cor. fence.
5	....	....	*e*	46° 35′	Cor. fence.
4.......	....	....	*d*	332° 28′	Cor. house.
3..............	....	....	*c*	331° 19′ 30″	Cor. house.
2..........................	....	....	*b*	330° 27′	Cor. house.
1......	....	....	*a*	306° 18′ 30″	B. M.
0............... ...... ▲	31° 17′ 30″	211° 17′ 30″	○	....	....



TO FACE PAGE 226 [This plate should have been made the exact size of the page of notes facing it.]

16..

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will point to zero also. If the magnetic meridian is *not* the adopted base, then the reading of the needle, when the α—vernier reads zero, should be = the deflection of whatever base is selected from the magnetic north. It is advisable to make this test at every hub, before and after all sights have been recorded, to make sure that, in first place the instrument has been correctly set, and secondly that it has not been disturbed during the work.

Proceed in a similar manner from station to station, taking always for α— reading, when setting the instrument, the β— reading to this hub, from the one previous. Thus the needle need not be read with minute care more than once—at the starting point—and still every angle throughout the survey has reference to one and the same course, the magnetic meridian.

If a greater number of objects are to be located than can be conveniently recorded in the columns designed for that purpose on the left-hand pages in the field-book, *i. e.*, if the topography of the country adjoining the line must be fully represented, then it would probably be advisable to have a separate book for that purpose.

I have seen no transit book of desirable dimensions containing sufficient space for such notes: but for a limited number of side objects the writer has found it convenient to put a letter opposite each sight and a corresponding letter at the respective objects, which are sketched approximately on the right-hand or topography page (see the accompanying sample pages), thus avoiding otherwise necessary description opposite the angles, whereby both time and space are saved.

In triangulation the "full circle system" is of still more value, as, besides the advantages already recorded, the surveyor has here many opportunities of easily testing the correctness of the work. Sights should be taken from each triangulation station to as many others as can be distinctly seen.

Then, at each station in turn, the surveyor is afforded as many means of testing the instruments, as indicated by the number of other stations from which observations have been taken to this one, by comparing the α— and β— readings to and from these respectively.

How to keep the field-book is exemplified by the sample pages before referred to, and will hardly require any further comments.

These are, however, designed for the running of a transit or meander line. For triangulation, one page or more, according to circumstances, to the left in the book is devoted to each station, the right-hand pages being occupied by topographical sketches, triangles, etc.

3. *The Office Work.*

Under this heading we will consider, first, the preparatory computations, and secondly, the plotting of the notes.

For accurate work the co-ordinates for the instrument stations, or any other points of particular importance, should always be calculated, whether the work is done by meandering or triangulation, this being the more important in proportion to the extent of the territory covered by the survey: for even the most carefully made protractor will fail to give a perfect and reliable result, and the errors are of course apt to mul-

tiply as the map is increased in dimensions, or the stations in number.

Here does the "full circle system" again show a remarkable advantage over the "quadrant system," for when the adopted base of reference is taken as ordinate axis, all angles required for the calculation of the co-ordinates are directly obtained in the field, whereas in the "quadrant system" these have to be computed from the field notes, a frequently laborious and tedious task, with always more or less waste of time, and in many instances with additional chances for making errors.

The common field-book for transit work might be used according to the principles of the "full circle system" as indicated by the sample pages. The one to the left in the book has six vertical columns, of which the first should contain the number of stations in the usual manner, the second and third the α and β— readings of the transit line, the fourth the reading of the needle, the fifth the α reading of miscellanous objects and the sixth any remarks or notes that may suggest themselves during the progress of the work.

In the column headed the "Needle" should be noted at each station the reading of the needle, *when the α— vernier reads zero.* This should naturally always be zero, when the magnetic meridian is the base of reference. If again this base has a deflection, of say 20° from said meridian, then the needle should, if the instrument is set correctly, read 20°. If it does not so read, the instrument has been set wrong, which should be promptly corrected before any work is done.

The β readings for miscellanous objects may be omitted, where the surveyor is well accustomed to read the instrument and does his work with exceptional care, but as a check or detector of errors it is however otherwise always to be recommended.

To plot the map is very simple. If an approximate accuracy is all that is required, or if the line surveyed is comparatively short, then co-ordinates, though always preferable, may not be deemed necessary. In such case the location of the starting point (zero) should first be marked on the paper, and the base of reference drawn through this point. Then with the protractor lay down the courses of the transit line and other objects as noted, with reference to said point and base. For this purpose it is preferable to have a protractor with a whole circle, divided, in conformity with the instrument, from zero to 360° and furnished with a vernier. In this case the α—readings are plotted directly as recorded. If a half circle protractor must be used, then all the angles in the α column which are less than 180° may be plotted first, in the space representing the first and second quadrants, after which the protractor is placed over the other half circle and the remaining angles plotted by the β, readings respectively. Through each following station, draw first the base of reference, and then proceed in a similar manner.

If the co-ordinate system is employed, then, after all stations have been duly plotted, which, by the way, should always be done by a carefully constructed net of squares, with sides representing not more than 1,000 feet within which the scale may be used.

The base of reference should be drawn through each station, after which other objects may be located as before described.

The same rules are, of course, applicable to triangulation stations.

These and other details will, however, soon become self-evident to any surveyor who has once made himself familiar with the system.

The many advantages of the "full circle system" will be better conceived and appreciated by actual experience in the use thereof than they can be by the most exhaustive description.

It may, however, not be amiss to make a brief recapitulation of what has been said, on purpose to draw particular attention to the merits of the system.

All the angles recorded, having reference to *one* course, instead of being referred to a combination of two of the four points of the compass, secures a very desirable simplicity, and excludes many chances for confusion and errors.

The columns for the magnetic and the corrected courses are here superfluous, the a— reading being always identical with the corrected course. The column headed the "Needle" is of course identical with the magnetic course, and though not absolutely necessary, may be used to advantage as a reminder to the surveyor of testing the correct position of the instrument when set up.

The observations of both the verniers, which are necessary in all cases where *reverse* readings are required, as has been demonstrated in the foregoing, are also very valuable checks, as in case of an error in the reading or recording of the one, it will be easily detected, and *might* be corrected, by comparison with the other.

As an example, to show how closely the base of reference may be retained (throughout the survey), I may state that at the survey of Calumet River last fall the difference between the bearing of a line as recorded in the field notes at the termination of the survey (about seven miles from the starting point), and the corrected bearing of the same line did not exceed one minute. The corrected course was obtained by successive corrections of all the courses, from repeated angles in each triangle.

The work of calculation and plotting is to a considerable extent reduced in quantity and simplified as to character, both of which are valuable features, not only on account of the time saved, but also for the less liability of errors.

The great simplicity of the system was forcibly impressed on my mind by the perhaps more practical than strictly logical expression which my kind and enthusiastic instructor made use of at the time of my initiation. He said: "As soon as you have only got the instrument properly set, you can go right to work, *without thinking at all.*"

This expression struck me at the time as a rather peculiar one, and I have often recalled it since, finding that the more I *think* about it the more I think *of* it.

CHANGING THE GAUGE OF RAILROADS WHILE IN OPERATION.

By Henry C. Thompson, Member of the Civil Engineers' Club of Cleveland.

[Presented September 14, 1881.]

In changing the gauge of a railroad in operation, it is in every way desirable that the traffic should be interrupted as little as possible, not only because of the absolute loss sustained by having a large amount of valuable property unproductive: but, by delays and serious interruptions, business becomes diverted into other channels, and considerable trouble will be experienced in bringing it back. Hence it becomes necessary that the change in the gauge should be done in the shortest possible time consistent with thoroughness, one day being ample to fully accomplish all the work if proper intelligence and forethought is put into the organization. In fact, the whole success of the undertaking depends upon a correct estimate of the work in hand and a proper organization and placing of the forces required.

Considerable preliminary work can be done with the regular repair men, with a possible increase of about 50 per cent. in the force if the gangs are small, and here it might be pertinent to say that a first-class chance is presented for spending money unnecessarily. Careful judgment must be used, so that neither too much nor too little expenditure in men and material is made. Watch closely the work as it progresses, increasing the force as the work multiplies and the time for preparation lessens, using the greatest care in having material promptly supplied to the men and in providing a sufficient force to use it as furnished.

The first work is cleaning the ballast from the tops of the cross-ties—which is done with shovels and brooms—and the object of it is to facilitate the adzing of the ties which follows, and the moving of the rails to their new position on the day of the change.

Next in order is the removing of all decayed cross-ties, supplying their places with sound ones. The main reason for this is, that for several days after the change is made the track is not fully spiked, and for safety it is important not to depend upon a doubtful tie to hold the rail in position.

The next step is spotting or adzing the cross-ties. This consists in cutting faces or seats on the ties where the rails are to lie in their new positions, and has for its object the preservation of the surface of the track without disturbing the beds of the ties. For this purpose a "spotting gauge" is used, in design similar to that shown in Fig. 1, of the accompanying plate. In this work the best results are obtained by placing two men on each section of five miles, who shall devote their whole time to it. They soon become adept and perform the duty with more speed and thoroughness than if changed about.

The only tools used on the day the change of gauge is made are spike mauls, claw bars and lining bars; and as the supply must necessarily be large, they should be made as nearly as possible of material and in form that they can be converted to other uses after the special work is done.

Spike mauls should be made of steel or of iron with steel faces (experience proving that iron is unsatisfactory), and lining bars of the same size and quality of round iron as is used on the line for coupling links, and of a length which is a multiple of what is required for a link.

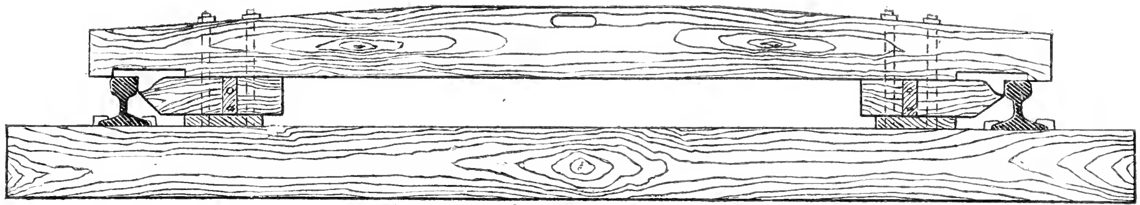
Under the head of frogs and switches, the first work to be done is to send to the shops all the extra switch rods to be changed to suit the new gauge, so that as few as possible of new ones will be required.

Placing the frogs and switches in the new and proper relative positions which they should occupy after the gauge is changed on the day the change of gauge is made requires care and intelligent work on the part of the foremen and men, as failure here will cause serious delay to the whole work. And to insure accuracy and safety the work should be thoroughly tested. The head block should not be, but the frog should be moved. Both rails of the lead should be thrown in, and previously a closure should be cut equal in length to the distance the frog is moved from its original to its new position, and when the change is made this closure is moved to the opposite end of the frog, thus filling the vacancy made by moving the frog toward the head block. This is evident because the length of a lead for a given frog angle depends upon the gauge of the track: the wider the gauge the longer the lead, and vice versa.

In ordinary stub switches it is better to change the rods on the day of change. The preliminary work here is to remove from each switch two rods, leaving four, and on the day of change put on four only; this is quite safe enough for a time. It is preferable to have the four extra rods on hand at the switch, made for the new gauge only, instead of making the rods for the double gauge and placing them in position previously. A good device for a split switch rod (found to work entirely satisfactory) is to cut the rod and weld on the end of one piece a section of gas pipe, in which two slots are cut, and on the other part of the rod cut two slots; then by means of a key the rod can be changed at pleasure to suit both the old and the new gauge. (See Fig. 2 of accompanying plate.)

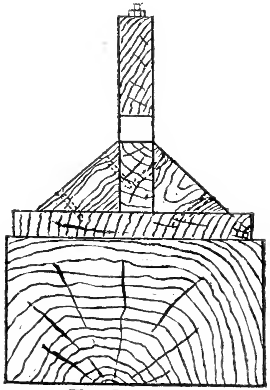
While the preparations are going on for the track all bridges, open culverts and cattle guards should be examined, and all defective stringers replaced with sound ones. The stringers should then be moved to the proper position for the new gauge, and a piece one-half width bolted on the outside of each to insure security pending the change of gauge. See Fig. 4 of accompanying plate. This additional piece can be removed after the gauge is changed if thought desirable.

On the day before the change all inside spikes, not absolutely necessary for safety should be removed. On tangents, where everything is in good condition, five spikes to a rail 28 feet long will be sufficient to leave, that is, one at each joint, quarter and centre. On curves more may be necessary, depending upon the radius, but rarely more than seven would be required. The inside spikes for the new position of the rail are all set before the day of change, and for this purpose a "spiking gauge" is used. This tool allows the trackmen to set the spikes exactly to the new gauge, and at the same time does not permit the spikes to be driven so far but that the base of the rail can be readily placed under the heads of the



Elevation Scale 3/4" to 1'

Fig: 1



End View

Fig 1 Scale 1½" to 1'

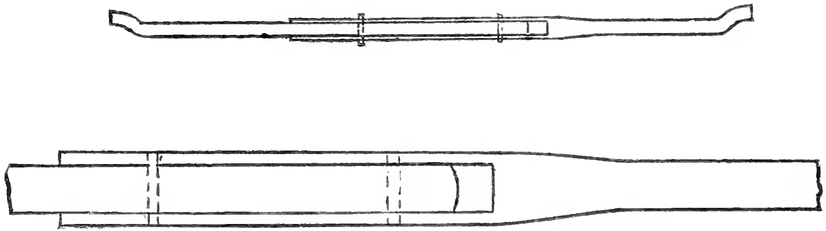
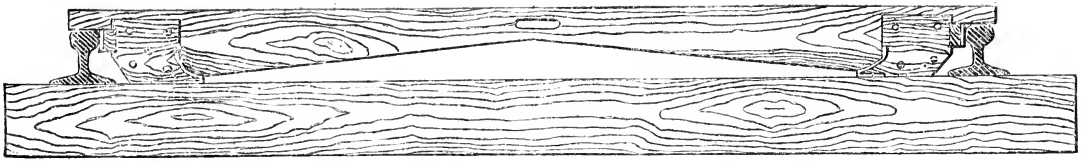
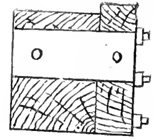


Fig 2

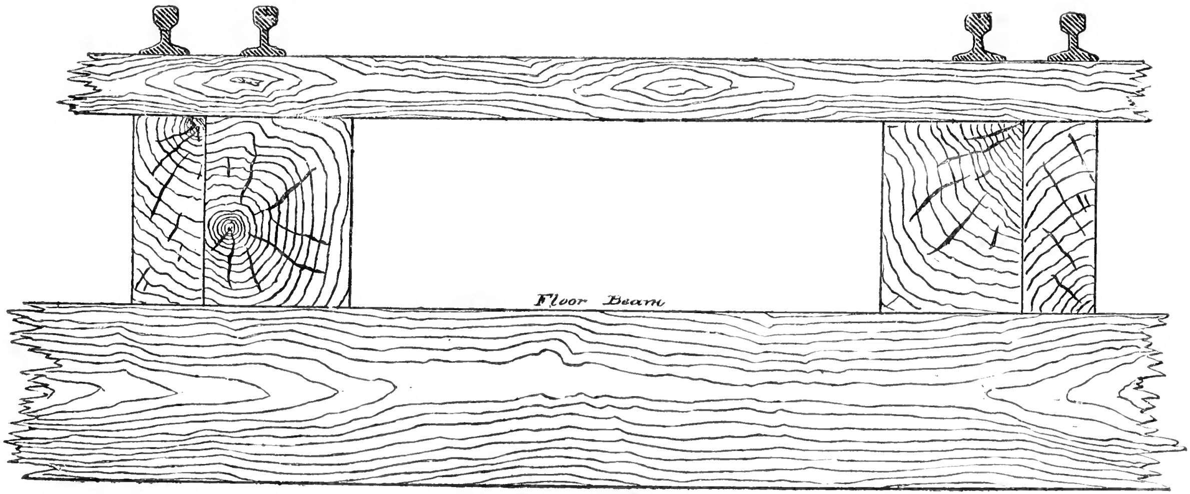


Elevation   Scale ¾" to 1'



End View Scale 1½" to 1

Fig 3



End View, Scale ¾" to 1'

Fig. 4.

spikes. (See Fig. 3 of accompanying plate.) The same rule as to the number of spikes to be set should be followed as in drawing the old spikes. New spikes should invariably be used for this purpose, because the uniform faces enables the trackmen to set them to a gauge. The work of setting the inside spikes should be commenced three weeks before the day fixed for changing the gauge. New spikes should also be distributed in the same proportion as is observed in setting the inside spikes. In setting the new spike a uniformity should be observed so that when the track is complete the inside spikes will all be on one side of the centres of the ties and the outside spikes on the opposite sides.

As in reducing the gauge of a track the outside rails on curves are shortened and the inside lengthened, all curves should be measured previously, the shortening and lengthening calculated for each twenty rail lengths, and proper closures provided.

An important matter not to be overlooked is to provide each section with a hand car and a truck car of the new gauge previous to the change. so that after the change is made the men will not be embarassed or delayed in the work which follows.

The grade crossings of other railroads should be prepared by providing other closures between the frogs. This is best done by making them in three pieces. the middle piece of each being equal in length to the total distance two opposite frogs are to be moved, then when the change is made these middle pieces are taken out and the remaining two pieces of the closures are brought together and bolted.

Bearing in mind that during all the preparations for changing the gauge of a railroad there is no interruption in the traffic. it necessarily follows that after the gauge is changed considerable rolling stock will be lying idle awaiting the work required to conform it to the new order of things. Provision should be made at the points where the work is to be done so that the rolling stock can be handled both before and after the change. This is done by third-railing the tracks at these points, and necessitates some novel combinations for switches, which will be described further on.

The requirements of tools and materials being fully grasped and provided for, the next point to consider is the necessary force to properly use them. A proper force for an ordinary track repair gang is a foreman and five men on each section of five miles; but that the work of changing the gauge may be done rapidly an increase of force is necessary. By experience, this force is found to be, for each section of five miles, two gangs of a foreman and twenty-two men each with water boys, and they should be men accustomed to track work. This extra force is usually supplied by neighboring lines. Good judgment must be used in receiving these men, that they may be placed in their proper positions and provided with accommodations for eating and sleeping, and returned promptly to their respective roads after the work is finished. For example, a line 200 miles long would have forty sections of five miles each. The force required to change the gauge would be 1920 men, from which deduct the home force, 240 men, would leave 1680 men to be provided for and to have ready in proper gangs at forty different places in time to begin the work, and to be returned to their respective roads after the work is fin-

ished. As one single mistake might cause the failure of the whole undertaking: to guard against such a misfortune, the engineer in charge must study the subject with care and coolness, thoroughly comprehend exactly what is to be accomplished, and imbue his assistants with his feelings and understandings, and then go ahead with full confidence in success.

The time set for changing the gauge having arrived, and all preliminary work having been done, there is nothing left but to faithfully carry out the programme and instructions previously determined upon. As an example of what a proper programme should be, and what instructions are necessary, I will quote the record of thenarrow gauging of the New York, Pennsylvania & Ohio Railroad, and of it, having taken an active part both in the preliminary and final work, am able to say that the programme was a complete success and was carried out faithfully, and that the work was done as set forth.

RECORD OF NARROW-GAUGING.

The N. Y., P. & O. R. R. was narrow-gauged west of Leavittsburg on June 22, 1880, for 222.1 miles: the remainder of the main line from Leavittsburg to Salamanca, N. Y., being third-railed.

The Mahoning Division was also narrowed up from 4 feet 9⅜ inches gauge to 4 feet 8½ inches, the latter work having been done gradually and not yet fully completed. A record of the narrow-gauging by sections is published in the report of last year's road-masters' meeting, from which it appears that work was begun very uniformly at 4 A. M., and the *average* time of completing the narrowing of the main line was about 8 A. M., the first section having been completed at 6.25 A. M., and the last at 10.30 A. M. Regular trains began moving on to the narrowed track about 2 P. M., and the regular inspection trains following up narrow-gauging met at Galion at 4 P. M. No accident and no serious interruption of traffic occurred.

The following was the special circular of instruction for narrow-gauging on June 21–22, 1880.

The track to be narrow-gauged is as follows ;

No. of Sub-Divis.	Name of road master.	No. of sections.	Track to be Narrow-Gauged.		
			Main track.	Siding.	Total.
4..........	Joseph Newham. John Newham.	7	27.0	8.0	35.0
5..........	H. Burgess. T. G. Armstrong.	9	45.8	9.3	55.1
6..........	M. J. McInarna. E. Collopy.	9	45.7	10.0	55.7
7..........	J. W. Alsop. P. Collopy.	11	54.6	7.6	62.2
8..........	D. Ryan. R. French.	10	49.0	10.0	59.0
		46	222.1	44.9	267.0

Both rails are to be thrown in, from 6 feet gauge to 4 feet 8½ inches.

1. The allowance of force is two gangs of 22 men each, with water boy extra for each section of 5 miles or thereabouts.

2. On or before the day previous to the day of change, the men are to

RECORD OF NARROW GAUGING BY SECTIONS, JUNE 22, 1880.

REMARKS.—The length of section given includes, on some sections, considerable distances which had been laid with N. G. rails before June 22. In figuring out the *hours work of one man to narrow one mile* these distances were deducted. Many of the fluctuations are due to differences of sidings, etc., some of the sidings having been narrowed up at the same time with main track, and others subsequently.

No. of section.	Name of Foreman.	Length of section as narrow gauged. From M. P.	To M. P.	Length miles	Force, including foreman.	N. G. work begun.	Main track completed.	Hours work of one man, including foreman. Total.	Per mile.	Av. No. spikes per rail. Driven.	Pulled.	Main track laid to N. G. before June 22.	Side track narrowed or laid N. G. before June 22.	Narrowing sidings. Begun at.	Completed at.	Left B. G.	Distribution of gang. Pulling spikes.	Lining.	Driving stubs.	Driving spikes.	Foremen.	Remarks
						A. M.	A. M.							A. M.	A. M.							
14	Thomas Donegan...	165	166¾	1¾	48	4:00	8:20	208	Yd.	8	6	.....	......	4:00	8:20	.....						
15	E. Smith.........	166¾	171½	4¾	43	4:00	7:30	151	31.7	5	3	.....	0.3	10:00	11:00	.....	6	6	1	8	2	All sections report that the arrangements for feeding and lodging, supply of tools and force were satisfactory, and that the spiking and work generally was well done.
16	T. Murray.........	171½	176½	5	51	4:35	8:00	173	34.6	7	3	.....	0.05	4:00	4:20	.....	4	6	2	12	2	
17	J. Thomas.........	176½	181½	5	52	4:00	6:25	125	25.0	8	5	.....	......	6:30	7:00	.....	4	6	2	12	2	
18	John Armstrong...	181½	185¾	4¼	54	4:00	9:00	270	57.0	5	5	.....	1.0	11:00	11:30	.....	6	6	2	10	2	
19	Fred Sudds.........	185¾	190¾	5	52	4:00	7:45	195	39.0	6	5	.....	......	....	....	.....	6	8	0	10	2	
20	Geo. Dennis........	190¾	192½	1¾	49	4:08	10:30	310	Yd.	8	6	.....	0.15	10:30	12:00	.....	8	8	0	10	2	
S. D. 4	Jos. Newham, R. M..	165	192½	27½	349	4:06	8:13	1,432	37.5	7	5	....	1.50	....	12:00	.....	5	7	1	11	2	
1	C. Erickson	192½	197½	5	56	4:00	7:25	190	38.0	6	5	....	All.	Narrowed the day before.		.....	6	6	1	13	2	
2	Wm. Mathews	197½	202	4½	65	4:00	7:21	217	48.2	6	5	.....	"			.....	6	6	1	13	2	
3	W. C. Cummins....	202	208	6	63	4:00	7:40	233	42.3	6	5	0.48	"			.....	6	6	1	12	2	
4	Jos. Shrenick......	208	211¼	3¼	22	4:00	8:00	236	39.5	6	5	0.10	"			.....	6	6	1	12	1	
5	Ed. Malone........	211¼	214½	3¼	51	4:00	8:15	217	37.4	6	5	0.46	"			.....	6	6	1	12	1	Do. Do.
6	Ed. Gier............	214½	221	6½	57	4:05	7:25	190	35.5	6	5	0.15	"			.....	6	6	2	14	3	
7	Jno. Mahoney.......	221	226½	5½	65	4:00	8:00	260	49.0	6	5	0.20	"			.....	6	6	2	12	2	
8	H. Surman..........	226½	232	5½	47	4:00	8:15	200	47.0	6	5	1.25	"			.....	6	6	1	10	2	
9	Jos. Strainick.......	232	238	6	47	4:00	7:45	176	34.5	6	5	0.91	"			.....	6	6	1	10	2	
S. D. 5	H. Burgess, R. M.....	192½	238	45½	473	4:01	7:37	1,919	41.3	6	5	3.55	9.3			.....	6	6	1	12	2	

10	Geo. Strainick	238	243½	5½	50	3:55	6:55	150	27.3	5	4½	....	0.05	3:55	6:00	..	6	6	1	10	2	Do. Do.
11	J. A. Hull...........	243½	249	5½	48	4:00	8:00	192	35.0	5	4	....	0.81	4:00	8:00	....	6	6	1	10	2	Gang made up of farmers.
12	C. W. Steinnetz.....	249	253½	4½	55	3:35	7:07	193	42.7	6	5	....	1.50	3:40	7:07	....	6	6	1	12	3	
13	J. H. Walsh.........	253½	259	5½	47	4:00	7:10	150	30.0	6	4¼	0.5	....	....	....	....	6	6	1	8	2	
14	Robt. Barry.........	259	264½	5½	45	4:10	8:00	171	38.0	6	5	1.0	0.38	8:00	8:30	....	6	6	1	8	2	
15	Pat. Hagerty	264½	269	4½	69	3:55	7:00	214	47.6	6	5	....	3.00	3:50	7:00	....	8	6	2	15	3	Twelve men under Tim Walch, act ng fore man, narrowed three miles of this section in three hours. At the rate of twelve hours labor per mile.
16	Jerry Driscoll	269	274½	5½	53	4:10	8:15	212	38.5	6	5	....	....	....	....	....	6	7	1	10	2	
17	Robt. Gordon.......	274½	280	5½	46	4:00	8:00	184	36.8	7	5	0.5	0.38	8:00	9:15	....	6	6	1	8	2	
18	L. Erickson........	280	280¾	0¾	67	4:55	6:00	74	Yd.	6	6	1.0	4.80	4:00	7:30	....	9	8	2	12	3	
S. D. 6	M. J. McInarna, R.M.	238	280¾	42¾	480	4:04	7:23	1,540	37.0	6	5	3.0	10.92	....	9:15	....	6	6	1	10	2	
1	T. O'Neil...........	283¾	288½	4¾	58	4:12	9:00	278	54.3	5	5	1.0	2.00	7:00	P. M. 5:00	0.25	6	6	1	10	3	
2	Wm. S. Dill.........	288½	293¾	5¼	48	4:05	8:15	202	38.4	4	4	....	0.30	P. M. 3:00	4:00	....	6	6	1	8	2	
3	Jas. Morris.........	293¾	299	5¼	51	4:00	8:55	250	47.6	4½	4	....	0.10	A. M. 6:55	A. M. 9:10	....	6	6	1	8	2	
4	D. Cusick...........	299	304	5	51	4:00	8:30	230	45.9	6	6	....	0.14	....	....	0.14	6	6	1	8	1	Five sections report bad spike mauls, and three that some of the men were somewhat negligent.
5	R. Muller...........	304	309	5	57	4:10	8:00	217	43.3	5	5	....	0.64	....	....	0.27	6	6	1	8	1	
6	O. Duross...........	309	313¾	4¾	49	4:00	7:10	157	33.0	7	6	....	....	8:00	9:00	....	6	6	1	9	2	
7	Thos. Hannegan.....	313¾	318¾	5	52	4:00	7:30	182	36.4	5	5	....	0.50	....	....	....	6	6	1	8	2	
8	P. McGrevey........	318¾	323¾	5	46	4:00	9:55	255	51.0	5	5	....	0.62	....	....	0.29	6	6	2	8	1	
9	M. Lyons...........	323¾	328¾	5	54	4:08	8:05	211	42.1	5	5	....	0.27	P. M. 4:30	P. M. 5:30	....	7	7	2	12½	3	
10	John. Armstrong....	328¾	333¾	5	48	4:00	8:45	228	45.6	5	6	0.84	0.88	1:00	5:00	....	6	6	2	8	2	
11	Michael Brown......	333¾	338½	4¾	52	4:03	9:00	260	59.0	6	6	0.30	0.10	A. M. 4:00	A. M. 9:00	....	6	6	2	9	2	
S. D. 7	J. W. Alsop, R. M...	283¾	338½	54¾	566	4:03	8:28	2,470	45.2	5	5	2.14	5.55	....	9:10	0.95	6	6	1	9	2	
12	D. O'Donnell.......	338½	343½	5	54	4:00	7:30	189	54.0	6	3	1.50	0.17	8:00	9:00	....	5	6	1	12	2	
13	John Mitchel.......	343½	348½	5	49	4:12	7:40	172	34.3	5	3	....	....	8:00	8:50	....	4	6	1	10	2	
14	Ed. McNary.........	348½	352	3½	58	4:00	6:50	164	46.9	5	4	...	0.23	6:50	P. M. 4:00	....	..	..	....	....	..	
14	M. Gannon	352	353	1	25	4:00	7:58	100	Yd.	5	4	....	0.23	8:00	4:00	....	..	..	....	....	..	
15	M. Gannon	353	358	5	49	4:00	7:30	172	40.0	6	3	0.75	0.23	8:40	A. M. 10:25	....	5	6	1	11	2	
16	M. Horrigan........	358	363¾	5¾	24	4:10	7:10	72	32.0	6	3	2.75	0.38	8:30	9:20	....	2	3	1	10	1	No complaints or deficiencies.
17	E. O'Donnel........	363¾	368	4¼	46	4:00	7:52	179	42.2	5	3	....	0.15	8:25	9:45	....	5	5	0	11	2	
18	John O'Neal........	368	373	5	49	4:10	9:00	240	48.0	6	3	...	0.57	10:00	10:50	....	6	6	½	10	2	
19	John Costello	373	378	5	55	4:12	8:40	248	49.5	6	4	0.03	0.40	11:00	P. M. 1:00	....	5	6	1	11	2	
20	S. Collins.........	378	383¾	5¾	48	4:15	7:50	178	30.9	5	3	....	0.25	8:50	A. M. 9:40	....	6	6	½	10	2	
21	Matthew Fearson...	383¾	386	2¼	23	4:20	7:30	76	38.4	5	3	0.31	....	None to narrow.		....	4	6	1	10	1	
S. D. 8	D. Ryan, R. M......	338½	386	47½	480	4:08	8:33	1,790	41.6	5½	3½	5.34	2.61	....	A. M. 10:50	None.	5	6	1	10	2	

be distributed and organized; sidings narrowed that can be spared and all spikes drawn that can safely be removed.

3. Not less than 5 new spikes per rail should be distributed in advance in the centre of the track.

4. All short rails for the outside of curves should be inserted in advance. If the "expansion" be too great, insert two pieces of iron rail, temporarily.

5. Place spare tools at convenient points on each section in case of breakage. Also have spare tools in each of the special narrow-gauge trains.

6. Let each road master have a light test gauge.

7. Place the men the night before near the point where they are to commence work in the morning.

8. Engage a water boy for each gang of 22 men, or two if circumstances seem to require it.

9. Men from sub-divisions 1, 2, 3, 4, 10, 11 and 12 will remain as long as circumstances require and permit to assist in completing the spiking and putting the track in condition generally.

10. See that all arrangements as to price for boarding and lodging the men are definitely fixed in advance. Road masters will certify to the correctness of all such bills before turning them in for payment.

11. The location and movements of the special narrow-gauge trains will be as follows :

	Miles.	
Train A, Leavittsburg. (Chief Engineer and John Newham.)	118.85	Will run through to Galion.
Train B, Ravenna (Jos. Newham).	20.10	Will work east, passing Train A at Freedom and bringing in all P. & L. E. men.
Train C, Ravenna (T. G. Armstrong.)	16.75	Will work west to Akron and return to Ravenna, bringing in all C. & P. men.
Train D, Akron (H. Burgess.)	21.50	Will work west to Russell, returning with all Valley and C. Mt. V. and C. men.
Train E, Russell (P. Bowen.)	14.50	Will work west to West Salem, returning with Tuscarawas Valley men.
Train F, West Salem (M. J. McInarna.)	30.50	Will work west to Mansfield, leaving no foreign men behind.
Train G, Mansfield (E. Collopy.)	15.50	Will work west to Galion, returning with all foreign men from Mansfield.
Train H, Galion (J. W. Alsop.)	20.25	Will work west to Marion, returning with C., C., C. & I. men from Galion.
Train J, Marion (P. Collopy.)	23.00	Will work west to Broadway or North Lewisburg as ordered, returning with all foreign men from Marion.
Train K, Urbana (R. French.)	25.75	Will work east to North Lewisburg or Broadway as ordered, returning with men for Urbana yard, and making a second trip if necessary, to bring in foreign men to Urbana.
Train L, Urbana (D. Ryan.)	34.25	Will work west to Dayton, leaving no foreign men from Dayton behind.
Train M, Dayton (H. C. Thompson.)	103.25	Will run east to Galion, and, if possible, without too much delay, bring in foreign men to Urbana.

Instructions for Work on the day of Change.

12. The track will be cleared of all trains, and work will begin at 4 o'clock A. M., and will continue without pause until the main track has been thrown in and made safe for trains.

13. No stopping on account of rain or ordinary bad weather.

14. Pay is $1 per man in addition to regular pay.

15. A double gang of 22 men, including foreman, will be stationed at each end of each section. One man or more from the home section will be detailed, if circumstances require, to work with the foreign gangs.

16. Each gang will work toward the middle of their section until they meet the gang from the other end of the section.

17. Each gang will be divided off about as follows, subject to variation as may be found necessary:

Six men, three on a side, pulling spike.

One sub-foreman, with spike maul, to drive stubs.

Six men lining.

Eight spikers.

One foreman, with extra spike maul in case of breakage.

Twenty-two men—water boys not included.

18. Let the men exchange work when they get tired, if advisable.

19. The same ties will be spiked on the outside as are spiked on the inside.

20. The inside spiking is all done on the east side of the tie, therefore be careful to drive the outside spike on the west side of the tie.

21. All spikes must be driven with care and perpendicular to the tie.

22. The inside spikes are already driven, but must all be tapped down to a good bearing. Foremen must be especially watchful to see that this is done. Every spike must be in good condition.

23. There are two very important cautions: Work rapidly, and work with deliberation. Do your work well.

24. Every effort will be made to have every man well lodged and well fed.

25. Each man should know the name of his foreman for the day and the number of his gang, so that distributing trains may not be delayed.

26. Dinner for part of the force will be carried on the special trains, which will be run over the track as fast as narrow-gauged.

27. The main track will generally be narrow-gauged first. As fast as the main track is completed, men will be moved ahead by the special trains to narrow any unfinished sidings or other work behind.

28. So soon as these special trains have completed their run they will return to pick up the foreign gangs and return them to their respective roads.

29. Every foreman is desired to note the time of beginning work in the morning and of completing the narrow-gauging of main track.

30. Each foreman from foreign roads will keep the time of his own men, and report it as his own road master may direct. Foreign men will be paid by their own roads and not by this road direct.

31. It is expected to have the track ready to run trains 2, 3 and possibly 5 through on time on the 22d. The last regular broad-gauge passenger trains over the road will be trains 2 and 3 on the 21st.

32. When the track is ready for the passage of trains, road-masters will make the following report to me. "Narrow-gauging complete and road ready for business." CHARLES LATIMER, Chief Engineer.

Distribution of Men on the 21st.

Men from sub-divisions 1, 2, 3, 4 and 9, S. & A. R. R. and P. & L. E. R. R., will go west on train 5 of the 21st.

Men from sub-divisions 10, 11 and 12, C. & P. R. R., Valley R. R., Tuscarawas Valley R. R., C., C., C. & I. and Columbus & Toledo R. R., also most of those from the B. & O. R. R., will go west on extra train 1, running very nearly on the time of regular 7, and leaving Leavittsburg at 9 A. M.

Men from the Pittsburgh, Fort Wayne & Chicago, N. W. Ohio, part of those from the B. & O. R. R., and those from the Pan Handle, C. H. & D. and D. & M. R. Rs. will be moved by special trains, or otherwise, as found convenient.

By experience gained in the work, I would suggest a few additions to the instructions, which would, in my judgment, be warranted by diminishing the risk of delay from accident, or from the failure of any part of the force to perform in season the task allotted.

1. Each pilot train shall carry eight spikers and four liners with their proper tools. These must be experienced men, and must not work on the first section until after two hours have elapsed, and then work two hours only, unless there is evidence of delay, the object in restricting their labor being to keep them fresh for an emergency. These men must not be carried after the engineer has assurance that his division is complete.

2. The pilot trains must be provided with wrecking frogs and four kegs of spikes, and have with each train a good man who is practically familiar with rerailing derailed cars and engines.

* The cost per mile of changing the gauge of a railroad, not including the rolling stock nor any new rail or cross ties, but including all labor, material and tools properly chargeable to the account, may be safely put down at $260 per mile. During the year 1880 locomotives were changed from a 6-foot gauge to 4 feet 8½ inches gauge at an average cost of $2,520 42/100, and in 1881 at an average cost of $2,919 10/100, the greatest cost for any single locomotive being $3,479 71/100 in the year 1881.

During the year 1880 cars were changed from 6 feet to 4 feet 8½ inches gauge at an average cost as follows:

Passenger cars	$75
Baggage cars	73
Mail cars	75
Caboose cars	25
Stock cars	25
Other freight cars	25
Tool and derrick cars	25

Distribution of the cost of changing the gauge of 222.1 miles of main track and 44.9 miles of side track on the N. Y., P. & O. R. R. in the year 1880. The wages paid was $1.15 per day and $1 extra on the day of the change—

Labor.	Adzing ties	$8,112.69	
	Laying narrow-gauge rails	1,523.32	
	Changing switches	2,851.74	
	Pulling and driving spikes and moving in rails	19,515.44	
	Spiking track in full	8,876.01	
			$40,879.20
	R. R. crossings	$799.24	
	Bridges	2,978.34	
	Timber structures other than bridges	5,151.11	
	Pits in engine houses and shops	3,129.77	
	Changing switch fixtures	886.24	
	Moving tool houses	14.50	
	New spikes	13,029.00	
	Hand cars	930.96	
	Tools	384.05	27,303.21
	Total		$68,182.41

* The above figures are taken from the published accounts of the cost of changing the gauge of the N. Y., P. & O. R. R. from a 6-foot to a 4 feet 8½ inches gauge.

In concluding my remarks. I will add that it is not necessary that the work should be done on Sunday. nor would I advocate that the peace and quiet of any community should be disturbed by bringing in a large number of men and engaging in such work on that day. As evidence of the thoroughness with which the work can be done. I will state that the pilot train under my direction when the gauge of the N. Y., P.& O. R. R. was changed. ran an average speed of 30 miles per hour over the new gauge. and that the first express train leaving the west end of the road at 2 P.M. on the day of the change. made its schedule time over the entire portion of the line changed. and that by the next morning all trains were running as usual and making schedule time.

NOTE.—The subject of third railing will be presented in a subsequent paper.

TRIBUTE TO THE MEMORY OF ALEXANDER L. HOLLEY.

BY J. F. HOLLOWAY, MEMBER OF THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read February 14, 1882.]

MR. PRESIDENT: In presenting the resolution at the opening of this meeting, I felt certain that I was but giving voice to the feelings of all members of this club who have had the pleasure of Mr. Holley's personal acquaintance, as well as those who knew him only by his published books, and by his accomplished works in the various steel and iron mills of our country. To those of you who have felt the warm. hearty grasp of his hand. who have seen upon his face the ever present genial smile, and who have listened to the sympathetic tones of his voice. a voice no less pleasant when expounding the most intricate theories of science, as when it sparkled with wit and humor, the news of his death will come with peculiar sadness It is not my purpose to occupy the time of this society with a recital of Mr. Holley's professional career: the technical journals and magazines that lie upon your tables have with more or less accuracy informed you respecting that. Neither do I intend to speak of his standing as an engineer in other and foreign lands. the papers that will in a few days reach you will tell of that also far better than I would be able to.

There is one aspect of his life and mission—I think I may call it a mission—about which I would gladly speak. and that is the rare combination there was in him. of the science of the savant, the practical knowledge of the workman, and the courtliness of the gentleman. Not content with possessing these rare qualifications in himself, he occupied the later years of his life in bringing about a new and better era of fellowship between science and practice in others. Standing as he did, the peer of any one in the ranks of either, he made himself the connecting link between men whose lives had been passed among books only. and the man of practice, who picked his uncertain way over hard and flinty roads, with patient toil and trial. It was his mission to bring the scientific man out from the libraries, colleges and the laboratories, into the smoke and grime of the world's workshop. On the other hand, standing beside his fellow workmen in the mine. the furnace and the workshop, he told

them that by study, by investigation and by interviews with men of science they could find many a clue to the difficulties that beset them from day to day. He told them if they would go with him to the laboratory with their troublesome ores and metals, that the man of science would, by ways of his own, hunt and drive out the demons that so troubled and baffled them in the furnace, the forge and the foundry, and in the various processes through which they so blindly chased them. And the man of practice, though ever distrustful of science, taking the advice of a fellow workman, took his ores and his metals to the laboratory, where the man of science calcined them, triturated them, and sublimated them: he bathed them in acids, dried them in alkalis, and, melting them in crucibles, brought out a tiny button of metal, and a folio of profoundly written formulas, replete with figures which divided a unit into ten thousand parts. Out of all this, by comparing the results without understanding them, the workman saw that the more he had of some things, and the less he had of others, the better would be his iron and his steel, and in the end he had a higher regard for science and a greater respect for the man of books; while on the other hand, the college professor, wandering among the mills, furnaces and workshops, was struck with the ingenuity and good sense displayed by the engineer, and thought the more highly of him.

But the mission of Alexander L. Holley meant more than this. He was not satisfied to simply bring each class to a better understanding and admiration of each other, he interested himself in the formation of societies where men of different professions, but kindred pursuits, might meet together to tell of the work they had in hand. Sometimes to speak of their success, often of their troubles and their failures. By the discussions which have taken place in these societies, all have been made wiser. Indeed it is safe to say that out of the greatest failures often has come the greatest good. In these societies are often found members who, in long years of practice, have gathered valuable stores of knowledge, but being unaccustomed to put their thoughts into words, were simply silent though interested listeners, these were induced to write papers which also came before the societies for discussion and record, and thus their printed transactions have come to be volumes of rare and valuable information, which not only does credit to their authors, but as well to the engineering literature of our country.

But there was still af urther step taken. Mr. Holley in his numerous trips abroad, oftentimes the guest of similar societies, early saw the advantage that would accrue to the industries of our country, as well as to the men to whose labors these industries owe their origin and success, if they could only be induced to leave their daily round of duties, and, joining with others, make excursions among the mills and workshops of their fellow workmen. Just how much good has grown out of this new departure can never be fully known. But it was not enough that the members of the societies should go, they must bring their wives with them, and those only who have availed themselves of these excursions which have so happily combined business, instruction and social intercourse, can in the least manner understand how enjoyable they have been, or how pleasant the acquaintances thus formed. I have spoken

thus somewhat at length, but by no means exhaustively, of the modern scientist, engineer and workman, that I might the more fully exemplify the part Mr. Holley has taken in bringing about so pleasant a state of affairs between them: and I do not hesitate to say that no man, no matter how high his position or his attainments, has done as much as did Alexander L. Holley to bind in one bond of kindly feeling and fellowship those who, as members and associates, have thus mingled together.

Among the many things he had doubtless planned for the future, and which, alas, are now unaccomplished, there was at least one, of which I knew, that it must have pained him to have left undone. It was this: he had hoped at some time in the near future to have brought before the various scientific and engineering societies of America, of which he was a member, a scheme by which they, joining together, should invite similar societies in England and on the continent, to send large delegations of their membership to unite in a grand tour through the United States, to be passed from State to State, and from city to city, seeing in each their different and distinct industries, to be taken down into our mines, carried on our broad rivers, borne upon our vast inland seas, and across wide prairies, far westward through States and Territories teeming with untold wealth, to the very portals of the Golden Gate. It was to be the excursions of all excursions, it was to excel by its extended field of observation, its immensity of proportions, and the standing and character of its members, the grandeur and brilliancy of all past time. It was to be a millenium of good feeling and of good cheer. All of you who have come in contact with and enjoyed the companionship of that wonderfully genial and kind-hearted man, can easily imagine what a success it would have been, and how largely his personal endeavors would have contributed to make it so. But the times were not yet ripe for its accomplishment, perhaps the severe illness that overtook him abroad a year or more ago and the enfeebled state of his health since had warned him it was not to be: but let us at least give him credit for that largeness of heart which conceived the idea.

I have not said, neither did I intend to say, anything about what Mr. Holley has accomplished as an engineer. His works are his monuments. In many a valley from the Hudson to the Mississippi, from the mouths of numerous converters the lurid flames light up the hillsides and write upon the midnight sky the wonders of his achievements. It was of Mr. Holley the man that I wished to speak; and as I remember his cheerful humor, his ready wit, the keen retort that left no wound behind, I feel how powerless I am to convey to ears unaccustomed to his voice the magic of its tones. There was ever about him a coterie of choice spirits, and to have been a listener to the flow of good things that fell so unpremeditated from his lips was indeed a treat. There are times and occasions when words fitly chosen, harmonizing with the circumstances which surround speaker and listeners, touched with a cadence of feeling and earnestness, bring to the heart of the hearer something deeper and wider in their significance than the same words would do spoken by other tongues and with different surroundings. And yet, knowing this as I do, I am tempted to relate an incident in Mr. Holley's life which I, in common with many others, witnessed, and which none will ever for-

get. It was on an occasion during the Pittsburgh meeting of the Institute of Mining Engineers, when a few personal friends of Mr. Holley who had engaged with him one way and another in the study, erection and working of the modern Bessemer steel plant, desired to present him with a beautiful and costly piece of plate. The presentation was to take place at the elegant country seat of William P. Shinn, at that time the President of the society. It came at the close of several days of most enjoyable meetings and excursions; but as the evening upon which it was to take place came on, there came with it a drizzling rain-storm. Mr. Holley, who had not been well during the meetings, seemed quite used up, and, making up his mind to forego the pleasure of the evening reception, went to bed at his hotel. So quietly and carefully had the projected presentation been planned that neither Mr. Holley nor his wife and but very few members of the Institute had any suspicion or knowledge of what was about to be done. With the rain falling outside and Holley sick in bed, the promoters of the scheme were at their wits' end. At last, as they saw no way out of it, they took Mrs. Holley into their confidence and told her all that they had hoped to do, and how disappointed they all were. Realizing as she did the generous feeling and love for her husband which prompted the act, and seeing, too, how sadly disappointed they all felt over the situation, she promised to see what could be done. Going to the bedside of her husband, she told him how disappointed Mr. and Mrs. Shinn were that he could not attend their reception, and that many of the members, hearing that he would not be there, were half-inclined to stay away also. Holley heard her in silence. At last, with an effort, he roused himself, and, thinking only of his disappointed friends, said, "Help me to dress, and send down word that we are coming." A close carriage was procured, and, carefully wrapped up, he made the journey and appeared in the parlors of his friends amid a wild huzzah of delight from all present. I need not recount the strategy by which he was at last brought up to the table, whereon, inclosed in a beautiful case, the still more elegant present lay enshrined. I could not, much as I desire to do so, repeat the beautiful and touching address made him by Mr. Shinn in behalf of the donors. As he closed and, uplifting the cover, revealed the testimonial beneath, enriched as it was with the memories that clustered about the names written thereon, Holley was for a moment silent; the ever-ready tongue failed to interpret his thoughts. At length, amid a silence that was profound, he began his reply. He spoke of the love he had for his profession and of his earlier efforts as an engineer, then, coming to a later period of his life, he accorded high and generous praise to those friends who had so much aided and encouraged him in his various undertakings. As he proceeded, it seemed as if a gleam of the future opened up before him, and he spoke of his work as about accomplished. Casting, as it were, a retrospective glance over the past, thinking doubtless, as indeed we all must at times think, how it might have been purer, better, there flashed across his mind the beautiful simile of the converter—the converter about which he had so much dreamed and planned—and he remembered how it, taking the impure and crude materials of the earth, earthy, through its alchemy, transmutes them, purified and purged from all defects, into a pure and noble metal. So, too, of our lives; might not

they, chastened, purified and freed from all earthly dross and stains, come at last to be remolded anew into higher and nobler forms? But words fail to convey the beauty of his thoughts, the pathos of his voice, the pallor that was on his cheek, the far-away look that was in his eyes, will never be forgotten by those who with tear-dimmed eyes stood grouped about him. But he is dead, and as a warm friend and an eminent writer has well said: "Tears shed for such a man are no evidence of weakness; the world will go on and another will take up the work he has left unfinished, but Holley's place in the hearts of his friends will never be filled."

At the conclusion of this tribute, the Committee on Resolutions, consisting of J. F. Holloway, Charles Latimer and J. D. Crehore, submitted the following, which was adopted by a unanimous vote of the club:

Resolved, That the members of the Cleveland Civil Engineers' Club have heard of the death of Alexander L. Holley with profound sorrow and regret.

Resolved, That in the death of Mr. Holley the engineering profession of the world has lost one who not only contributed largely to the success of all industries connected in any way with metallurgy, being the father, as it were, of the Bessemer steel process in this country, whilst he also added largely to the highest order of our literature.

Resolved, That while he held a position among the highest of our profession, he will ever be remembered and mourned on account of his great personal worth and purity of character.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

APRIL 19, 1882:—A regular meeting of the Society was held at 7.30 P. M., President Doane in the chair; eleven members and one visitor present.

The record of the last meeting was read and approved.

The amendment to Article XVI. of the Constitution adopted at the last meeting was ratified. The article now reads:

ART. XVI. During residence fifty miles or more from Boston, any member whose dues have been fully paid may upon notice to the Secretary in writing retain his membership by the payment of three dollars per year, payable at the annual meeting, and be exempted from any other assessment.

Mr. Frank W. Hodgdon was elected a member of the Society and the following were proposed for membership: Mr. Samuel M. Felton, Jr., by Messrs. Doane and Tinkham, and Mr. Charles H. Swan, by Messrs. Doane and Rice.

A letter was read from Mr. L. F. Rice, tendering his resignation as a member of the Metric Committee. The resignation was accepted and the President authorized to fill the vacancy at his convenience.

The annual report of the Metric Committe was read and accepted.

Mr. H. A. Carson read some notes describing various wire rope tramways used in Europe, and also one designed by himself which was used in excavating the water ways in the Back Bay Park, Boston.

Mr. Chas. H. Swan, who was present by invitation, exhibited and explained various forms of metric chains, tapes and rules which were now found for sale.

[*Adjourned.*] S. E. Tinkham, Secretary.

METRIC COMMITTEE'S REPORT.

To the Boston Society of Civil Engineers:

The Committee upon the Metric System has but a brief report to make for the year last past.

It is not aware that the use of the Metric System has been adopted by any new countries during that time.

We have learned somewhat of the details of its use upon Mexican railways from letters of our former chairman, Mr. Fred. Brooks, and from the published correspondence of professional journals. These are of interest as showing how complicated a simple matter may be made when human ingenuity is bent on finding out how *not* to do it, and have already been informally read to this Society; but as they can hardly be considered as showing *progress* towards the extension of the use of the system, they cannot with propriety be introduced here.

On the other hand, the committee has not been informed that any country where the system is or has been in use has discarded it during the last twelve months, or that there is any immediate probability of such action taking place.

The American Society of Civil Engineers has desisted from printing with its publications the request that maps and plans may have metric scales attached; but the American citizen, without regard to age, sex, or previous condition, still possesses the privilege of using the system if he wishes.

In other words, the committee reports no progress, either forward or backwards.

L. Fred'k Rice, for the Comm.

Boston, March 15, 1882.

WESTERN SOCIETY OF ENGINEERS.

Tuesday, April 18, 1882:—The 145th regular meeting was held at 4 p. m., Vice-President Cregier in the chair.

Mr. Lyman Bridges, Chief Engineer California Central Railway and San Francisco & Ocean Shore Railroad, of San Francisco, Cal., made application for membership.

The application was indorsed by Messrs. Chesbrough, Cregier and Greeley.

[*Adjourned.*] L. P. Morehouse, Secretary.

May 2, 1882:—The 146th regular meeting was held at 4 p. m., Vice-President Cregier in the chair. The minutes of the preceding meeting were read and approved.

Upon ballot, Mr. Wm. H. Swanitz, Division Engineer Toledo & Northwestern Railway, Peterson, Clay County, Ia., was elected a Member and Mr. Charles L. Harrison, civil engineer, Lake Providence, La., was elected an Associate.

The Committee on Seal reported as follows, and the request of the committee was granted:

The Committee on Seal, to which was referred the matter of a certificate of membership, desire further time for its consideration. Respectfully,

Wm. S. MacHarg, Chairman.

The Committee on Portraits made the following report, which was received, and its recommendations adopted:

Your Committee on Portraits of the Presidents begs leave to report that it considers it very desirable that portraits of the President and ex-Presidents of this Society be obtained of life-size and uniform style. Excellent crayons, in every way suitable, can be obtained for a sum of not more than $30 or $40 each.

And we recommend that a committee of three be appointed to obtain portraits of the President and ex-Presidents in accordance with the forgoing report.

BENEZETTE WILLIAMS, Chairman.

The Chair appointed Messrs. Williams, FitzSimons, and Liljencrantz as Committee on Portraits to carry out the recommendations of the report.

The Committee on Prize Papers made the following report, which was accepted :

To the Chairman and Members of the "Western Society of Engineers:"

At the 122d regular meeting of this Society, March 1, 1881, a motion was made and carried, viz :

"That a committee of three be appointed to consider the questions recently brought before the Society, of giving an annual prize for the best paper presented during the year, and to report whether it is desirable or not to offer such prize."

Your Committee has the honor to report as follows :

It is hereby recommended that one annual prize be offered for the best paper, submitted to and read before the Society, by one of its regular members, during the year, provided that *any* such paper shall be regarded by the judges as worthy of a prize.

It is further recommended that such a prize shall consist of a gold medal, about the size of a twenty-dollar gold piece, one side to show the seal of the Society, the other, the name of the receiver of such prize, the subject of the paper—if practicable—for which the prize was awarded, and the date when it was read.

The Committee has investigated the probable approximate cost of dies, for minting, and also of manufacturing in embossed work, each medal separately, with the following result: The cost of dies would amount to about $200, to which must be added for each medal the cost of material, minting and engraving names, etc. Medals may be manufactured for each occasion for about $35 apiece, including material and all work.

Finally the committee would suggest that for judges, the Society shall elect, from among its members, such as are non-competitors for the year in question, are deemed the most competent and may be regarded by any and all members as absolutely impartial.

G. A. M. LILJENCRANTZ, Chairman,
BENEZETTE WILLIAMS,
WM. S. MACHARG.

On motion of Mr. Liljencrantz, the following resolution was adopted :

Resolved, That, at the appointment of all special committees, a certain meeting shall be decided upon, when the report of such committees shall be due, the length of time thus allowed to depend in each case upon the character of the duties of each committee, provided, that an extension of time may be granted, at the pleasure of the Society, and at the request of a committee, made at or before the meeting, when its report is due.

The Secretary read a letter from Mr. Chesbrough, of the committee appointed to prepare a memorial on the death of Mr. Hjortsberg, explaining the delay the committee in reporting, and afterward read the

MEMORIAL.

Mr. Maximilian Hjortsberg was born in Stockholm, Sweden, on the 8th of November, 1825, being the youngest of seventeen children, all of one mother. His father, Mr. Lars Hjortsberg, originally educated for the medical profession, was a highly gifted and cultivated man, his histrionic genius having been early noticed by the king, Gustavus III., and causing him in later life to be called the Swedish Talma. Maximilian received at first rather a short schooling, was then apprenticed to a prominent builder of Stockholm, and, during his apprenticeship, which seems to have lasted about two years, he learned to draw plans of

structures, in which he became very proficient. He then spent a year or more in the Polytechnic School of Stockholm, and about the year 1846 went to London, when, through the influence of the Swedish Minister, he was introduced to Mr. Robert Stephenson, and obtained the place of draughtsman in his office. He afterwards joined the staff of Mr. John Fowler, and was sent to Hull, where he was employed in the construction of the docks on the Humber, and the railways connected with them, till 1850. In that year he visited North America, traveling extensively in the United States and Canada. In 1851 he returned to Stockholm, but in 1852 he again went to America, where he settled permanently.

For a time he was engaged as one of a firm of contractors on a railroad in Southern Indiana, and had charge of a portion of the Ohio & Mississippi railroad, under Colonel Henry Flad, now Commissioner of Public Works in St. Louis, Mo. In 1857 he made Chicago his residence, and in the next year took a subordinate position on the Chicago, Burlington & Quincy Railroad, from which in a short time he rose to be the chief engineer. This position he filled until 1879, during which time he planned and constructed for that railway an important bridge across the Mississippi River at Burlington, and several branch roads. In the discharge of these duties he exhibited a thorough knowledge of details, and combined, in the works committed to his care, adaptability, durability, and economy, in such a manner as to leave no room for unfavorable criticism. A service like this, by far the longest and most important of his life, brought out traits of character and evidences of ability which caused Mr. Hjortsberg to be highly appreciated, and gave him an enviable position among the intelligent portion of the community.

During the last two years of his life Mr. Hjortsberg was much interested in the subject of furnishing steam to cities for heating buildings, and for motive power, from central boiler stations, through pipes laid in the streets, and became thoroughly convinced, not only of its practicability, but of its economy in many respects. His last position was that of engineer of the Pullman Palace Car Company at Kensington, about 16 miles south of Chicago. It was while in discharge of his duties there that he met with the very painful accident which caused his death about three weeks after, on the 16th of May, 1880.

In matters of taste, as well as engineering skill, Mr. Hjortsberg stood deservedly high; and his reputation in this respect caused him to be appointed twice the superintendent of construction of one of the most beautiful churches in the city; once before and once after the great fire. He was appointed by the Governor of the State in 1878, and continued until his death, one of the Lincoln Park Commissioners, an office without emolument, but requiring for the faithful performance of its duties great responsibility in the expenditure of money, much care and judgment in the adoption of plans for the protection of the drive, along the shore of Lake Michigan, from the effect of storms; and a combination of good taste and economy, exceedingly difficult to find, in the laying out and ornamenting of the grounds.

Mr. Hjortsberg was elected a Member of the Institution of Civil Engineers on the 5th of May, 1868. He manifested his interest in the advancement of engineering in this country by becoming a member of the American Society of Civil Engineers, and by assisting in the organization of our own Society, of which he was one of the original members, and was one of the Executive Committee from 1869 to 1873, inclusive. He was also a member of the Chicago Historical Society, and of the Chicago Literary Club, organizations that have for their object the faithful preservation of the records of the past, and the upholding of a high literary standard in the future.

In all relations with his employers, his professional brethren and society, he maintained not only the reputation accorded him already for ability in the discharge of his engineering duties, but for thorough uprightness that has never been called in question. He was somewhat reserved in manner, for which

reason those who did not penetrate the outward crust did not always understand, and could not correctly appreciate, him; but to those who shared his intimate friendship, his unusual intelligence, his fine taste in matters of literature and art and his personal excellence were not only manifest, but very attractive.

Mr. MacRitchie, for the Memorial Committee on the death of Mr. Lane, read the following

MEMORIAL.

Moses Lane was born in Northfield, Vt., Nov. 16, 1823, and died in Milwaukee, Wis., Jan. 25, 1882. He attended Norwich Academy, in his native State, and received instruction from the late Professor Buck, at that time Principal of the Academy. He then went to the University of Vermont, from which he graduated in 1845. He was first employed in engineering on the Sullivan Railroad in New Hampshire, and continued there less than a year. He was then employed till 1847 on the Vermont Central Railroad, when he took charge of the Springville (N. Y.) Academy, remaining till 1853. In 1852 he married Miss Marinda Ingalls. On leaving Springville, Mr. Lane was appointed resident engineer, at Albany, of the Albany & Susquehanna Railroad, having immediate supervision of the Albany division. Upon the suspension of work on this road, about a year later, he took charge of the academy at Clarence, Erie County, N. Y., remaining three years, when he was appointed principal assistant engineer of the Nassau water-works to supply the city of Brooklyn, N. Y. These works had just been commenced under the late Mr. J. P. Kirkwood, who afterward attained the highest rank among the hydraulic engineers of this country. At the end of five years Mr. Kirkwood retired from the charge of the work, and Mr. Lane was appointed his successor, having charge not only of the water-works, but afterward of the sewerage, which position he held for seven years, when, through the influence of ring politicians, he was left out by a change of administration. This was probably the bitterest trial of Mr. Lane's life, for, after having served the city faithfully for twelve years, he naturally looked upon his position as a permanent one, and had made all his domestic arrangements in that expectation.

After leaving the service of the city of Brooklyn, Mr. Lane was associated about two years with E. S. Chesbrough in the planning of sewerage systems for Indianapolis, Ind., and New Haven, Conn., and water-works for Pittsburgh, Pa., and other works of less importance. For the Pittsburgh water-works he was afterward employed a few months as consulting engineer, but here again he encountered ring politicians with the usual result. Well, the intelligent portion of that community are now satisfied that they have thrown away three millions of dollars, and, after floundering more than ten years, wish heartily they had not changed the original plans or mode of carrying out the work.

In 1871 Mr. Lane was appointed Chief Engineer of the Milwaukee water-works, which he planned and carried out; after which, in 1875, he was made the City Engineer, and as such had charge of the water works, sewerage, streets, bridges, etc., and was part of the time President of the Board of Public Works. In 1875 Mr. Lane was appointed one of the commissioners who devised a main drainage system for the city of Boston, which was afterward adopted in its general features for the south side of the Charles River, but modified in some important respects by Mr. Davis, the City Engineer, who, however, recognized the value of Mr. Lane's services. These works are now being carried out under the name of "Improved Sewerage," and are by far the most extensive of the kind yet undertaken in this country.

In 1878, owing to political influence, Mr. Lane was removed as City Engineer of Milwaukee, after which for upwards of two years he was employed as consulting and designing engineer in different parts of the country principally, in a most important improvement, almost a renewal, of the New Orleans water-

works; in planning water-works for Knoxville, Tenn.; as one of the Commissioners for the proposed Buffalo (N. Y.) Intercepting Sewer; for Erie, Pa., sewerage; he was also consulted relative to Kansas City, Mo., and Topeka, Kan., water matters, also one of the Commissioners for the sewage disposal problem of Milwaukee.

Mr. Lane's knowledge and experience as an hydraulic engineer caused him to be appointed Chairman of both of the commissions for testing the Chicago west side pumping engines. He was appointed a commissioner for similar purposes by the cities of Boston, Mass., and St. Louis, Mo.

In April, 1881, Mr. Lane was again appointed City Engineer of Milwaukee, and was ex-officio President of the Board of Public Works, the duties of which positions he continued to perform until January 20, 1882, when he was stricken with apoplexy, against which his strong and vigorous constitution struggled wonderfully until his death, fifteen days after the fatal attack.

This brief statement of Mr. Lane's professional career shows it was one of the most remarkable of our country, and yet he was so far from making the slightest effort to appear conspicuous that only his intimate friends appreciated his ability, worth and great usefulness. Many with far less real claims have received much greater pecuniary rewards, as well as temporary favor. But though he felt all his life the need of a moderate competency, he considered the possession of wealth of less importance than filial and other obligations, the fulfillment of which always kept him in moderate circumstances. His life, however, in this, as in other respects, already referred to, illustrated the proverb, "A good name is rather to be chosen than great riches." Successful men are now gratefully saying all they have and are they owe to him. A distinguished engineer feels that "it was a happy privilege" of his life that he "was brought under the influence of the example and character of Moses Lane," and says, "I always felt sure that I should do exactly right when I followed his advice." In short, Mr. Lane's kindness and liberality to the full extent of his means, not only to his family connections, but to friends and associates, are too widely known to need further mention here. Probably no practicing engineer in this country has had under his training so many eminent men, not only members of his own profession, but of the bar and other callings.

Mr. Lane had an unusually fine physique, a large head and chest of Websterian type, with which family he was distantly connected.

To these natural powers the advantages of a thorough educational training were added, and he thus started on his professional career with qualifications that fitted him to attain the highest eminence. That he richly merited this, the various important interests committed to his judgment and care abundantly show.

Mr. Lane's family at the time of his death consisted of his wife, son and three daughters, who are left to mourn the loss of a husband and father whose thoughtful care anticipated every want, and whose intelligent and affectionate watchfulness afforded them constant protection and guidance.

It was voted that the Memorials read at the present meeting be entered upon the records, and that manuscript copies be sent by the Secretary to the families of the deceased members.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

MARCH 11, 1882:—The 2d annual meeting of the club was held at the rooms of the Windsor Club, Bank street.

The Programme Committee had arranged a substantial supper for the benefit of the members, previous to the regular exercises of the evening. Promptly at

8 o'clock, between 50 and 60 members, with a few invited guests, sat down to supper, which was served in most acceptable style by the Windsor Club.

After refreshments the members adjourned to an upper room, where the regular business of the evening commenced with Col. J. M. Wilson in the chair.

In the absence of the Recording Secretary the reading of the minutes of the last monthly meeting was dispensed with. Petitions for membership were received from Messrs. J. F. Pankhurst, A. F. Taylor and John Eisenmann, which were laid over under the rules. S. T. Wellman, C. E. Burke and C. B. Krause were elected to active membership.

Annual reports of officers were called for. Recording Secretary C. H. Burgess being absent, no report. M. E. Rawson, Cor. Secretary, stated that his duties had been mainly such as pertained to the matter of joint publication, as would appear in that report to be read at the proper time. Treasurer James S. Oviatt presented his report in full, showing total receipts $476.34 ; disbursements, $288.07 ; cash on hand, $269.47, with a paid membership of 71.

Owing to the length of the evening's programme, the reports from standing committees and on joint publication were postponed until next monthly meeting. Vice-President Col. J. M. Wilson then delivered his annual address, giving a retrospect of engineering from ancient to modern times, with many suggestions to the profession of to-day. The address was listened to with much interest and received hearty commendation at its close, and upon motion of Mr. Leland was unanimously requested for insertion in full upon the journal of the club.

Mr. G. A. Hyde followed with an interesting paper upon the value of the Signal Service in its relation to the industries of the country, and urged its support. Prof. N. B. Wood read a paper on "Chemical Experiments without Instruments," and gave some experiments with marsh gas. He also exhibited an exceedingly delicate scale balance, the beam of which is made of *rye straw* and the pans of alumina, the whole weighing only fifteen grains, but capable of weighing to *one ten-thousandth part of a grain.* A piece of hair one inch long was found to weigh $\frac{1}{1000}$ of a grain by this delicate instrument, which Mr. Wood believes to be the most delicate scale recorded.

Gen. M. D. Leggett, president of the Brush Electric Company, spoke of "The Future of Electricity as a Motive Power." He believed that unless we shall discover some cheaper methods of generating it than is now known, electricity, as a motive power, will be mainly used for light machinery, by using powerful generators in central localities and distributing power to factories, stores, shops and dwellings where steam or other motive power is too expensive, or is impracticable. This will be done by the ordinary wire circuit and by the secondary or storage battery. He thought the time near at hand when street cars would be propelled by stored electricity, but so far as at present known, the great waste of power in generating the electrical force (which ranges from 15 to 50 per cent. of loss) will preclude its use as an independent motor, but that we are on the eve of wonderful discoveries regarding this subtle force of which we now know so little, and of its future none can tell.

Mr. John Whitelaw, engineer of the City Water-Works, read a carefully-prepared paper on "The Duty of the Steam Engine," which is worthy of preservation in our club records, but deserves to be extended so as to apply to our present engine duty.

J. F. Halloway read a humorous and instructive paper on the "Civil Engineer." Rev. J. W. Browne spoke of the increase of knowledge induced by these fraternal organizations, and Mr. C. P. Leland of railroads forty years ago, when strap rail and "snake heads" took the place of the T-rails and telegraphs of later years.

The annual election of officers then followed, which resulted in the unanimous choice of the following persons: For President, Col. J. M. Wilson, U. S. A.; Vice-

President, J. F. Halloway; Recording Secretary, M. W. Kingsley; Corresponding Secretary, Prof. A. L. Arey; Treasurer, Jas. S. Oviatt.

After returning a hearty vote of thanks to all who had contributed to the evening's entertainment, the club adjourned to meet on the second Tuesday evening in April. M. E. R.

APRIL 11, 1882:—A regular meeting was held Tuesday evening, President Col. J. M. Wilson in the chair. Minutes of last meeting read and approved. William Barr and Clarence O. Arey nominated for, and J. F. Pankhurst and Arthur F. Taylor were elected to active membership in the club.

M. E. Rawson submitted his annual report as member of the Board of Managers on joint publication.

On motion the club was authorized to secure one dozen copies of Mr. Halloway's paper on Alexander L. Holley, for distribution, andthat copies be sent to Mrs. Holley.

The President appointed the following persons to serve on standing committees for the ensuing year:

Committee on Programme—N. B. Wood, Chairman; H. C. Thompson, Clarence H. Burgess, S. Sheldon and N. P. Bowler.

Committee on Library and Publications—J. D. Crehore, Chairman; John Whitelaw and A. H. Porter.

The President appointed Mr. S. T. Wellman, Superintendent of the Otis Iron and Steel Works, as third member of the committee to memorialize Congress to continue the tests of iron and steel. The other members of the committee, appointed at a previous meeting, are J. F. Halloway, Chairman, and J. A. Bidwell. The committee was requested to report its deliberations at an early date.

The following resolution, offered by Mr. Rawson, was adopted:

Resolved, 1st. That a committee be formed to be known as a "Committee on Membership," to which all questions pertaining to admission, suspension, or deprivation of membership shall be referred for investigation and report. And all applications for membership shall be approved or reported upon by said committee before being voted upon by the club.

Resolved, 2d. That such committee on membership shall consist of three members, to be appointed by the chair, who shall serve during the present fiscal year (unless sooner relieved), or until their successors are appointed.

The following persons were appointed a committee on membership: G. A. Hyde, chairman; J. N. Richardson and B. F. Morse.

Mr. Walter P. Rice, member of the club, then read a very interesting paper on "Observations on the Mouths of Lake Tributaries," giving the results of some observations made by him to determine the velocity and volume of water discharged at the mouth of the Cuyahoga River in the city of Cleveland.

A short recess was taken at the conclusion of the reading of the paper to allow the members an opportunity to examine the apparatus used by Mr. Rice in taking his observations.

The names of Mr. F. H. Strieby and Mr. J. E. Smith were nominated to active membership, which, with the names of Messrs. Barr and Arey, were referred to the Committee on Membership. The request of Mr. Edward Colgrove to withdraw his membership from the club was referred to the Committee on Membership.

On motion of Mr. Baker, the Committee on Library and Publication was authorized and requested to procure a suitable cabinet for preserving specimens placed in the club rooms.

The Secretary was requested to have printed a pocket calendar showing the dates of all regular meetings, together with a list of officers and members of standing committees, and the names and addresses of all members.

The thanks of the club were tendered to Mr. Rice for his paper. On motion, the club adjourned, to meet on the second Tuesday evening in May.

M. W. KINGSLEY, Recording Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.

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This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

EXPERIMENTS MADE WITH THE DEACON WASTE-WATER METER SYSTEM.

By Dexter Brackett, Member of the Boston Society of Civil Engineers.

[Read May 17, 1882.]

The waste of water, its causes and means of prevention, is a subject which is growing in interest to the water-works officials throughout the United States. The fact that from one-fourth to one-half of the water supplied in many of our large cities is wasted, is acknowledged by all of the engineers and superintendents having charge of the water supplies, but as to the best method of preventing this waste, there is some diversity of opinion.

The purpose of this paper is to give a description of some experiments which have been made during the past year upon the Boston water-works, in the prevention of waste by the Deacon waste-water meter system, together with some general statements in regard to the waste in this and other cities and the means adopted for its prevention.

The Deacon waste-water meter and the method of detecting waste by its use were invented by G. F. Deacon, M. Inst. C. E., Engineer of the Liverpool Water-Works, in which city it was first applied. In 1871 the daily consumption in Liverpool was 35 gallons per head, and the supply was furnished during but 9½ hours of the 24. This measure was employed to reduce the consumption, as the works were not of sufficient capacity to furnish a constant supply. An unsuccessful endeavor was made to obtain the passage of a bill containing a provision for controlling the waste, and from the necessities of the case was brought forth the Deacon system. By its use, between the years 1873 and 1876, the waste was so reduced that a constant supply was given, with a daily consumption of 30 gallons per head, and at the present time it is but 27 gallons, of which 9 gallons are used for trade purposes. The average consumption for the year 1880 was 1,200,000 gallons per day less than that of the year 1871, notwithstanding an increased population of 104,000.

So great was the success in that city that the system has been adopted in Glasgow, Hull, Blackburn and other English cities. In London the system has been applied to a population of 73,000 and is now being further extended. Its trial in Boston is the first use which has been made of the meter and system in this country, and as the consumption or waste of water in many of our American cities is about double that of our English brethren, the results obtained may be of interest with reference to the adoption of this system in other cities.

Before giving the results of the experiments a description of the meter and of the method of applying the system may be of interest.

The waste-water meter does not, like an ordinary water meter, record the quantity which has passed between any two observations, but it records on a diagram the rate of flow at each end and every instant. Being thus able to determine the rate of consumption during the night, when no water, or at least a very small quantity, is used for legitimate purposes, the water wasted can be distinguished from that used.

The meter, Plate 1, consists of a hollow cone having its small end upwards and containing a composition disk of the same diameter as the small end of the cone. A vertical spindle attached to the upper surface of this disk is suspended by a fine German-silver wire, which passes practically water tight through a small hole in the top of the chamber, over a pulley, and supports a weight.

This weight is so adjusted as to retain the disk at the top of the cone when the water is at rest. When any water is drawn through the meter the disk is pressed downward towards the bottom of the cone, its position depending upon the quantity of water passing through the meter.

A pencil, attached to the wire, records the motions of the disk on a drum revolving by clock-work once in twenty-four hours.

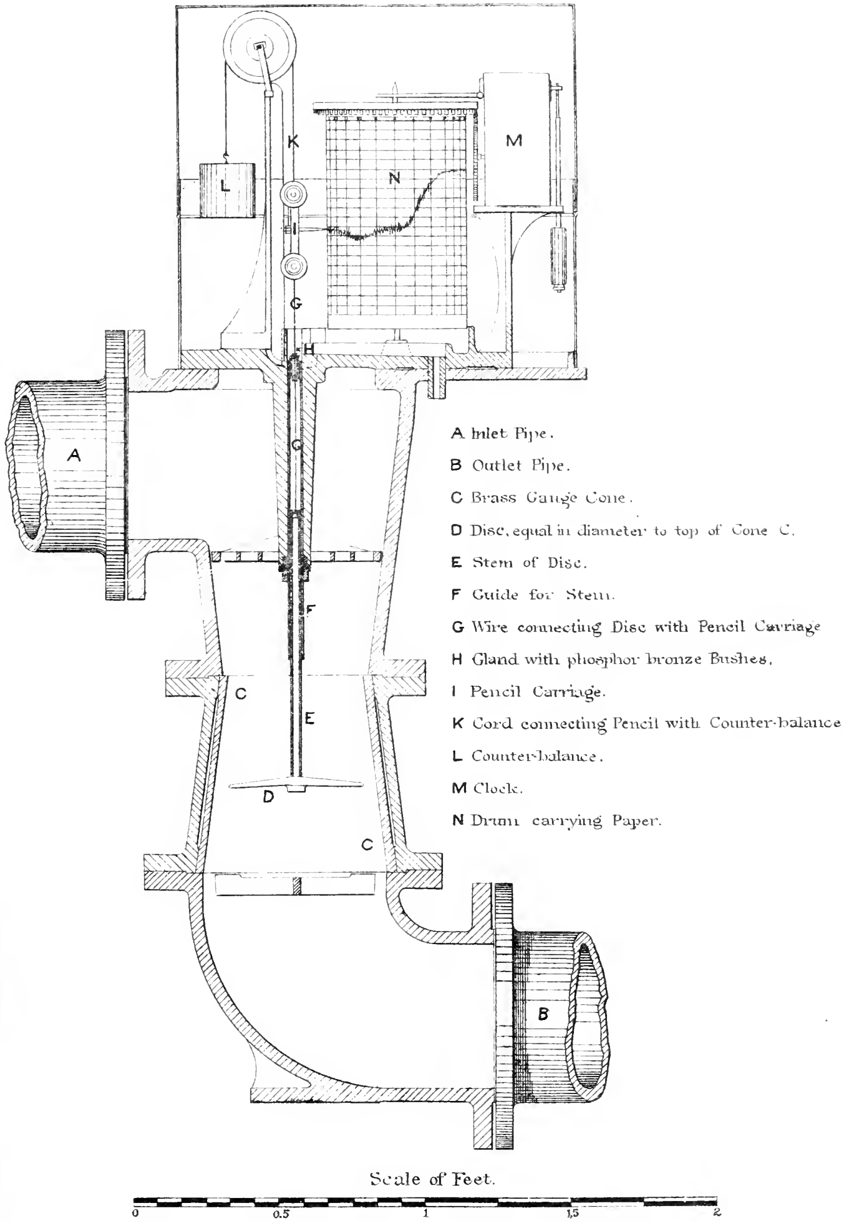
The method adopted for detecting, measuring and preventing the waste was as follows: Each meter was placed in a box under the sidewalk and connected with the street main in such a manner that by closing the valves on the street mains all of the water used in a certain section could be drawn through the meter. After a few diagrams had been obtained to show the ordinary rate of consumption, the inspection was commenced. The service pipes are all provided with stop-cocks, accessible from the sidewalk by means of an iron wrench about seven feet in length.

When this wrench is applied to a stop-cock the sound caused by water passing through the service can be easily distinguished.

When no noise is heard with the stop-cock full open, it is partly closed, and the increased velocity always causes a distinct sound, although the quantity of water passing the stop-cock may be very small.

The night inspector began his work about midnight, and tested each service pipe; if any flow was discovered, that stop-cock was closed and a note made of the time and the number of the house. This operation was continued until about 4 A. M., when he retraced his steps and opened all of the stop-cocks which he had found wasting. At the same time the waste-water meter was recording consumption and the diagram indicated the amount of water wasted by each of the service pipes closed, the time the inspector commenced and finished his work, and the time at which each stop-cock was closed.

SIX INCH DEACON WASTE WATER METER.



The Heliotype Printing Co. 211 Tremont St. Boston.

The day inspector received the night inspector's report, visited the premises where waste had been noted and ascertained the cause.

Notices were then issued to the owners or occupants of the premises, and in cases of waste from defective fixtures, the visits were continued until the repairs had been made. After the section had been examined by the above method, it was inspected by streets. This inspection consisted in closing the gate controlling the supply of an entire street, and thus proceeding through the section, gradually diminishing the territory supplied, until the entire section had been shut off. By this plan the amount wasting in each street was determined. If, by the records of the meter, the waste in any street was found to be disproportionately large, a night examination of that street was made to determine whether the waste was on the premises of the water takers or from the street mains or services. This fact was determined by closing all of the house services and then the gate on the main supplying the street. If the record of the meter showed that the closing of the main gate reduced the consumption, it was evident that the amount indicated was being wasted in the street.

The whole district experimented upon was divided into twelve sections. The outline of these sections and the location of the meters are shown on Plate 2. By making certain portions of some sections common to others, eleven of the sections were supplied by two of the meters without any change of location. Section 1 A was first tested in connection with a portion of Section 1, but after the waste had been reduced the two sections were combined.

The population, number of families, etc., supplied in each section is shown by the following table. The population given is based upon the average number of persons in each family as given by the census reports. This method, although not strictly accurate, is sufficiently so for the purpose of exhibiting the results of these experiments.

Number of Section.	Number of stop-cocks.	Number of families	Number of stores.	Number of stables.	Estimated population.	Average number of families supplied per stop-cock.
1	307	669	14	15	2,810	2.17
1 and 1 A	406	875	19	24	3,675	2.15
2	268	517	17	8	2,170	1.93
3	329	481	10	11	2,020	1.40
4	317	448	8	6	1,880	1.41
5	304	426	3	9	1,790	1.40
6	260	446	10	3	1,875	1.71
7	373	606	21	20	2,540	1.63
8	366	570	10	9	2,400	1.56
9	394	513	8	15	2,150	1.30
10	322	425	3	5	1,790	1.32
11	432	665	7	6	2,800	1.54
12	303	548	6	19	2,300	1.81
Totals	3,170	5,180	97	122	21,760	1.63

As the Charlestown District, when the experiments were made, con-

tained no sections devoted exclusively to business purposes, and as the manufacturing sections were generally metered, the sections were so selected as to exclude these portions of the district as far as practicable and also to combine in separate sections different classes of dwellings. Sections 3, 4, 5, 9 and 10 embrace the wealthier portion of the population, while sections 1, 2, 7, 8 and 12 are peopled almost entirely by mechanics and laborers.

RESULTS.

The work of inspection was commenced on May 10, 1881, and continued until November 18. One of the meters has been in use through the winter for the purpose of observing the effect of cold weather upon the consumption, but no means have been taken to prevent any of the waste. All of the sections were twice inspected, the inspections being made at intervals of two months, as near as circumstances would allow, that being about the length of time occupied in completing an inspection of the whole district.

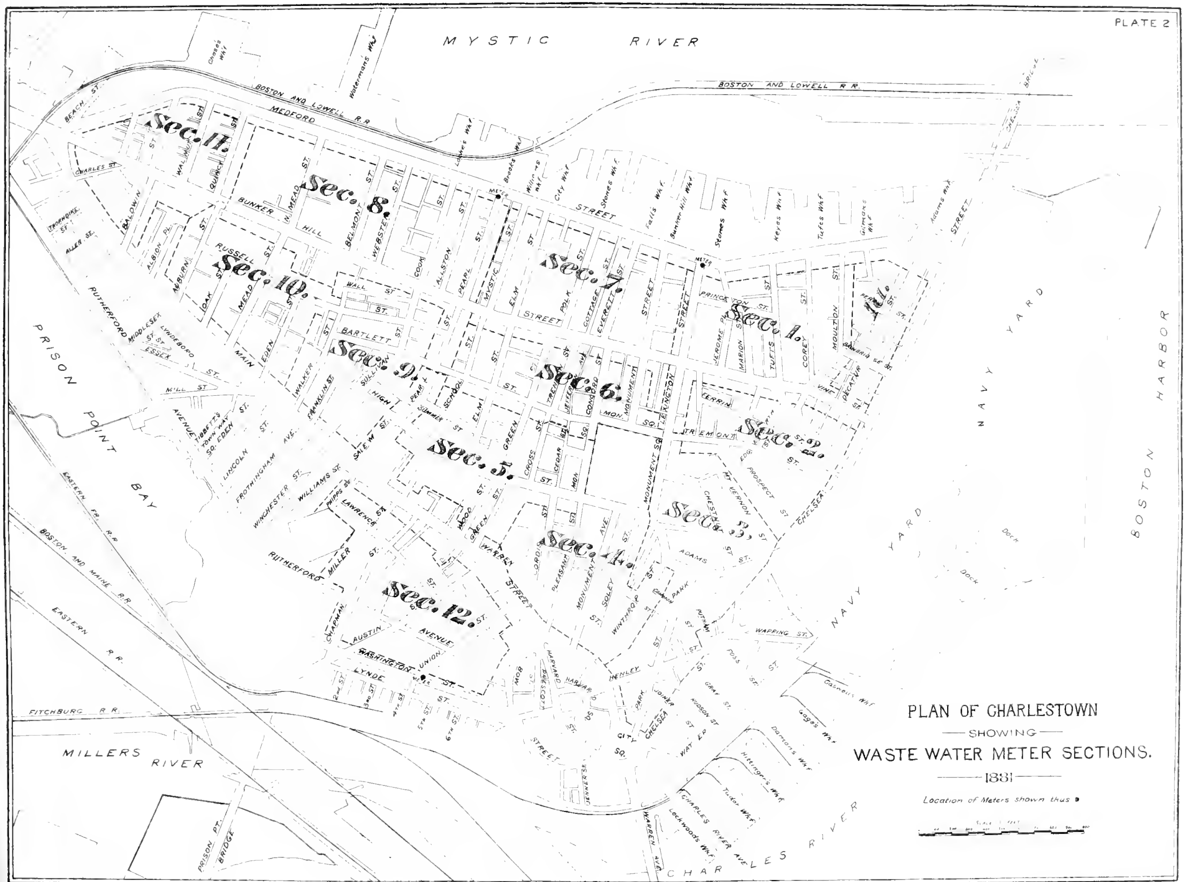
After the second inspection was concluded a few readings of the meter were taken from each section to show the result of the two inspections, and some of the sections were inspected a third time. The results accomplished are shown by the following table :

Number of Section.	Estimated population.	Number of persons per stop-cock.	Gallons per Head per Day.				Percentage of Reduction.	
			Before inspection.		After two or three inspections.			
			Total.	Night rate per 24 hours.	Total.	Night rate per 24 hours.	On total.	On night rate.
1	2810	9.2	53.5	39.1	26.4	10.6	50.7	72.9
1 and 1 A	3675	9.1	52	39.0	34.1	13.7	34.4	64.9
2	2170	8.1	49.9	33.1	36.7	13.2	26.5	60.1
3	2030	6.2	71.8	43.2	45.1	20.2	37.2	53.2
4	1880	5.9	68.4	42.2	47.8	22.3	30.1	47.2
5	1790	5.9	72.7	53.3	47.8	17.8	34.3	66.6
6	1875	7.2	60.	44.6	35.3	15.1	41.2	66.1
7	2540	6.8	55.2	31.9	39.6	19.2	28.3	39.8
8	2400	6.6	55.	40.8	37.9	18.5	31.1	54.7
9	2150	5.5	62.9	40.1	36.2	13.7	42.4	65.8
10	1790	5.6	52.3	28.1	46.1	18.7	11.9	33.4
11	2800	6.5	43.7	17.5	25.7	9.5	41.2	45.7
12	2300	7.6	80.4	55.2	31.2	12.5	61.2	77.4
Averages		6.86	58.5	37.5	37.7	15.8	35.6	57.9

From the above it appears that on the whole district covered by the inspection, containing a population of 21,760 persons, the average daily consumption was reduced from 58.5 to 37.7 gallons, a saving of 35.6 per cent. or 20.8 gallons for each person supplied, while the night rate was reduced from 37.5 to 15.8 gallons per head per day, a saving of 58 per cent.

The results of the inspections are graphically shown by the diagrams on Plates 3, 4 and 5, which show the rates of consumption in Sections 1, 5 and 12, both before and after the inspection.

The results obtained indicate that the wealthier class of the population are the largest consumers of water ; thus, for example, the consumption of sections 3, 4, 5, 9 and 10 at the close of the season was 44.6 gallons per head, while that of sections 1, 2, 7, 8 and 12 was but 35.9 gallons. The



PLAN OF CHARLESTOWN

SHOWING

WASTE WATER METER SECTIONS.

1881

Location of Meters shown thus •

above fact is corroborated by the following table, from a paper on the subject of waste by T. Stewart, student Institute C. E., showing the results obtained in Glasgow, Scotland, where the system has been in use for about six years:

Number of stop cocks.	Number of occupants at night.	CLASS OF PROPERTY.	GALLONS PER HEAD PER DAY. At starting of meters. Total.	At starting of meters. Night rate per 24 hours.	After first three inspections. Total.	After first three inspections. Night rate per 24 hours.
79	2,971	Good tenement houses, $60 to $120 rental, with a few inferior houses, $15 to $50 rental. About fifty shops, $150 to $500 rental.	60.0	42.5	34.0	16.4
98	731	High class property, chiefly self contained houses, $400 to $1,500 rental, with a few tenement houses $200 to $300 rental. No shops...	146.4	152.7	60.0	48.2
42	1,562	Old property, chiefly low-class tenement houses, about $10 to $40 rental, with a few better houses about $40 to $80 rental. A few inferior shops, $30 to $110 rental..	14.3	7.4	13.3	4.8

The conditions under which this system of waste detection has been tried in Glasgow correspond more nearly with those existing in Boston and other American cities than do those of other European cities where the system has been used. The supply furnished is constant and ample, and the proportion of water fittings to the population is larger than is common in most European cities.

The following table shows the results obtained in Glasgow from an inspection similar to the one made here:

Number of district.	Number of sub-districts.	Number of occupants at night.	Number of persons per stop cock.	GALLONS PER HEAD PER DAY. At starting of meters. Total.	At starting of meters. Night rate per 24 hours.	After first three inspections. Total.	After first three inspections. Night rate per 24 hours.
I.	9	14,972	25.8	71.0	54.0	40.9	21.1
II	6	10,002	22.4	79.0	72.2	50.4	33.0
III.	3	4,986	35.4	73.7	62.4	44.2	21.7
IV.	6	7,629	30.6	79.0	57.0	50.5	24.8
V.	7	9,815	:7.8	55.1	36.8	37.7	17.3
VI	8	12,614	39.7	37.2	29.5	27.1	17.8
VII.	2	4,132	25.5	45.5	30.6	41.9	25.8
VIII.	3	6.306	37.1	44.9	27.5	33.6	15.1
IX.	4	7,821	32.1	44.9	31.7	30.8	15.2
X.	2	3,012	34.6	44.2	33.4	25.0	12.8
Totals and averages.	50	81,289	30.6	55.8	45.2	38.4	21.0

A striking similarity exists between the above results and those obtained in Boston, thus the daily consumption per head was reduced from 58.8 to 38.4 gallons, in Glasgow, while the corresponding quantities for the Boston experiments were 58.5 and 37.7 gallons. The night waste was larger in Glasgow, but the amount of reduction corresponds very closely in the two places.

SOURCES OF WASTE.

The sources of waste may be divided into three classes.

1st. Defective services and fittings on the premises of the water takers.

2d. Defective mains and services on the premises of the city.

3d. Willful waste.

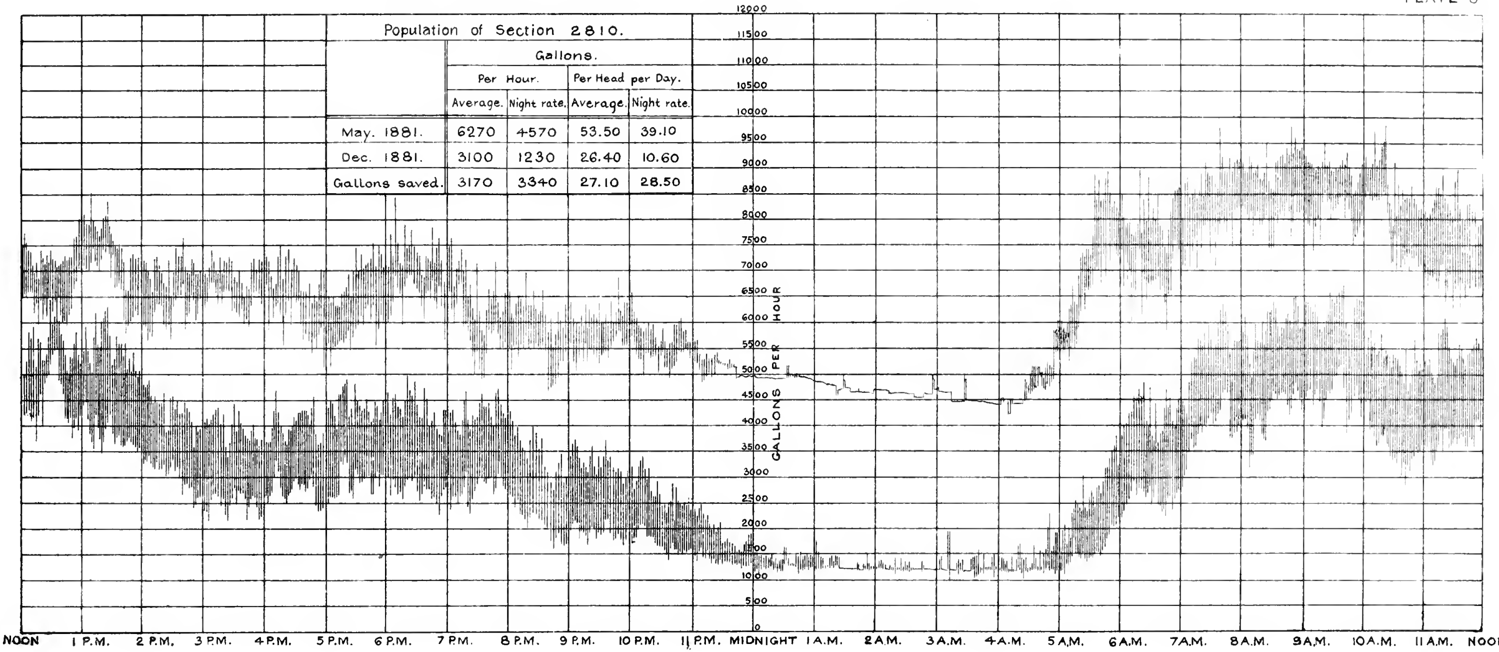
The following table enumerates the sources of waste which were discovered by the inspectors:

Number of Section.	Defective faucets.	Defective water-closets.	Defective services inside.	Defective ball-cocks.	Defective stop-cocks.	Defective yard hydrants.	Defective urinals.	Defective services outside.	Water-closets found running.	Faucets found running.	Totals.
1 and 1 A	42	47	5	1	4	1	1	6	17	1	125
2	16	20	2	1	...	2	....	1	5	1	48
3	12	14	2	5	2	....	....	...	8	....	43
4	5	17	3	6	....	....	....	1	5	...	37
5	10	35	1	5	....	....	....	....	15	....	66
6	8	32	2	2	1	....	...	...	13	2	58
7	8	38	6	2	2	....	1	6	8	....	71
8	30	36	11	1	4	....	....	2	13	....	99
9	12	19	7	2	...	1	....	3	9	....	53
10	9	20	1	4	....	....	...	1	4	....	39
11	13	12	2	1	2	....	...	2	3	....	35
12	26	53	13	2	....	....	....	2	24	....	120
Totals	191	343	55	32	15	4	2	24	124	4	794

DEFECTIVE SERVICES AND FITTINGS ON THE PREMISES OF THE WATER-TAKERS.

Defective services, when located within buildings, generally cause damage, and are consequently repaired; but when such defects occur where service pipes are carried through yards and passage-ways or under buildings which are without cellars, they are the source of large waste which is unseen and therefore unknown. The largest leak discovered was one of this kind. A wrought-iron service pipe supplying a stable was so destroyed by rust that it leaked throughout its entire length, wasting 1,000 gallons per hour. The result of closing the stop-cock on this service is shown on Plate 6. The pipe was laid in a porous filling, through which the water soaked away unseen. Of the defective fittings discovered by the Charlestown inspection, the water-closets were the greatest sources of waste. More than 300 of them were reported as needing repairs, and by the record of meters the aggregate waste of twelve water-closets was nearly 50,000 gallons per 24 hours. The water-closets used in this district are generally what are termed valve closets, that is, they are supplied directly from the street main, the shut-off cock being operated

WASTE WATER METER DIAGRAMS SHOWING RESULTS OF INSPECTION IN SECTION 1.



Population of Section 2810.

	Gallons.			
	Per Hour.		Per Head per Day.	
	Average.	Night rate.	Average.	Night rate.
May. 1881.	6270	4570	53.50	39.10
Dec. 1881.	3100	1230	26.40	10.60
Gallons saved.	3170	3340	27.10	28.50

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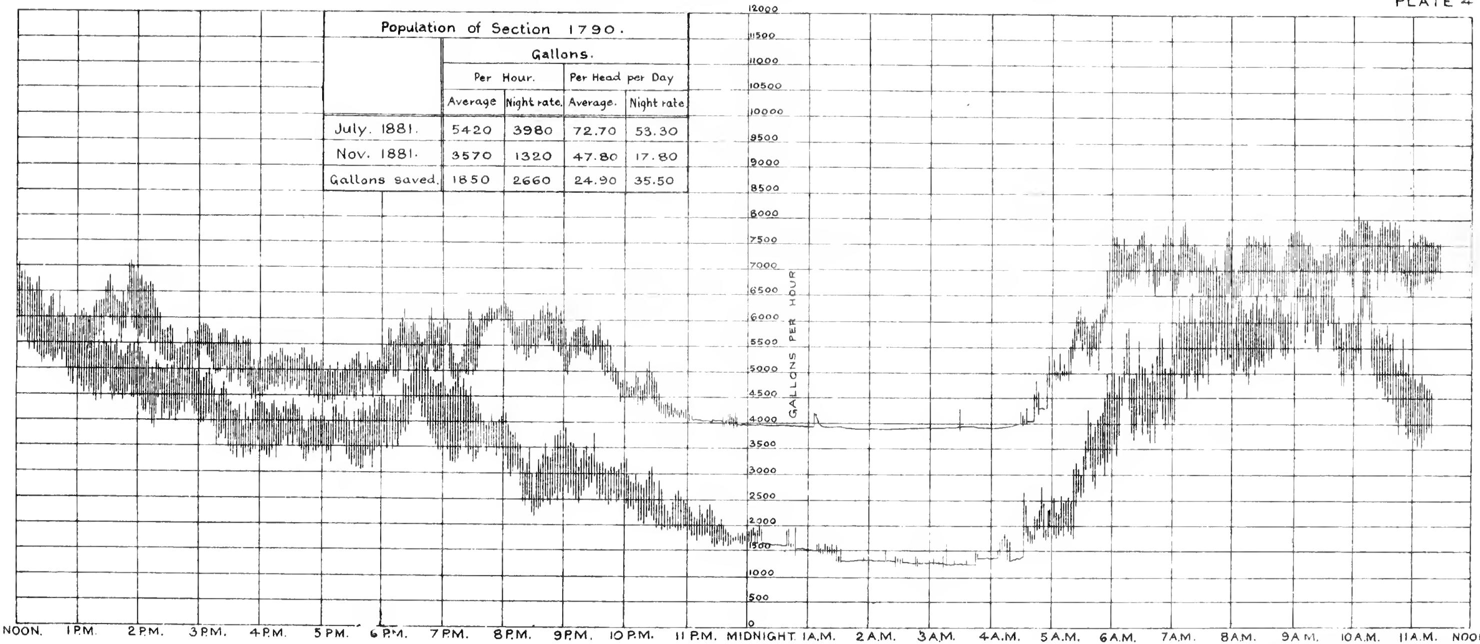
PLATE 4

WASTE WATER METER DIAGRAMS SHOWING RESULTS OF INSPECTION IN SECTION 5.

Population of Section 1790.

	Gallons.			
	Per Hour.		Per Head per Day	
	Average	Night rate.	Average.	Night rate
July. 1881.	5420	3980	72.70	53.30
Nov. 1881.	3570	1320	47.80	17.80
Gallons saved.	1850	2660	24.90	35.50



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by a handle and a counter-weight or spring. Very few of the water-closets receive their supplies from tanks, and the number of ball-cocks in the district is consequently small, nevertheless 32 defective ones were found.

In many portions of Boston, where this fixture is generally used, it is the source of enormous waste. The following illustration of this fact came under my observation a few years since. The application of a meter to the service supplying one of the finest buildings in the city, occupied by business offices, disclosed the fact that the night consumption of the building was 5,530 gallons, while during the day it was but 3,900 gallons. The water fixtures were all self closing, and as far as could be seen by a superficial inspection in perfect order: a careful examination, however, showed that the ball-cocks controlling the supplies of 16 tanks were defective, and that the water was constantly wasting, unseen, through the overflow pipes. The greater pressure during the night increased the waste at that time. The average daily consumption of the building for the year after the ball-cocks were repaired was 3,630 gallons, a saving of 5,800 gallons per 24 hours, or of $423 per annum to the owner of the building.

DEFECTIVE MAINS AND SERVICES ON THE PREMISES OF THE CITY.

When the Charlestown works were built in 1864–5 the distributing mains were all of wrought iron, coated inside and out with cement mortar. Fifteen years' use proved them defective, and they have been partially replaced by cast-iron pipes. It was expected that many leaks would be found from the cement coated pipes, but these expectations were not realized. In a few cases the closing of a main gate, after all the services had been closed, showed a waste of from one to three hundred gallons per hour from the main or from the services between the main and the sidewalk shut-offs, but no leaks were discovered of sufficient magnitude to warrant the expense of uncovering a long line of main pipe.

Twenty-four services were reported as wasting outside the premises of the water takers. The most important of these was a tin-lined pipe which had burst. About one-quarter of the whole number were small defects in the stop-cocks at the curb. The total amount wasted by all of the cases found was not more than 300 gallons per hour.

WILLFUL WASTE.

During the progress of the inspections 124 water-closets were discovered through each of which there was being wasted from 100 to 300 gallons per hour. These were not cases of negligence, but of *deliberate waste*, for the water-closet fixtures were in repair, and with few exceptions self-closing, and the waste could only be caused by the determined purpose of the occupants to allow the water to run.

Occupants of premises where this class of waste was found were notified that a fine would be imposed for a second offense, and it is a fact worthy of notice that although the inspections were made at intervals of two months, and their occurrence was unknown to the water takers, but five cases were reported the second time.

Another form of willful waste is that caused by the almost universal habit of allowing the water to run continually during the cold weather for the purpose of preventing the freezing of service pipes.

The following table and the diagrams on plates 7 and 8 show the amount of this waste in section 1:

TABLE SHOWING THE AMOUNT OF COLD WEATHER WASTE IN SECTION I.

Population of Section, 2,810.		Gallons per Head per Day.	
Date.	Remarks.	Total.	Night rate.
May, 1881	Before inspection.	53.5	39.1
Dec., "	After three inspections.	26.4	10.6
Dec. 29, 1881	Before cold weather.	27.6	9.2
Jan. 4, 1882	Cold.	61.5	52.3
" 22, "	Warmer.	35.8	20.5
" 23, "	Cold.	58.0	61.5
" 24, "	Colder.	82.0	77.9
" 25, "	Coldest.	about 100	88.9
	Waste on Jan. 25.	about 70	about 80

In this section the houses are without furnace heat, the plumbing so arranged that the pipes cannot be drained, and the tenants, knowing that the water, if not allowed to run, will be cut off by the frost, naturally take the only method left them to retain their supply.

This feature is graphically illustrated on Plates 7 and 8. The lower diagram on Plate 8 shows the average consumption in December, 1881, before the advent of cold weather, and the upper diagram shows the effect of a sudden fall in the temperature during the afternoon and evening of January 22. Between 8 and 10 P. M. the lower diagram shows a decrease of 1,000 gallons per hour, while the upper one shows an increase of 2,500 gallons, caused by the opening of faucets by people before retiring.

That the enormous increase shown by the above table is entirely due to his cause of waste, and not to increase in the waste from defective fixtures, is shown by the diagram on Plate 7.

The advent of cold weather, between December 29, 1881, and January 4, 1882, in six days more than doubled the daily consumption, while the night rate was increased from 9.2 to 52.3 gallons per head. Between the same dates the consumption of the whole Mystic system increased 60 per cent., or from 68 gallons to 109 gallons per head per day. This is not an exceptional case, in fact cases have occurred when the whole consumption has been more than doubled from this cause, and when the daily consumption per head was 170 gallons per consumer.

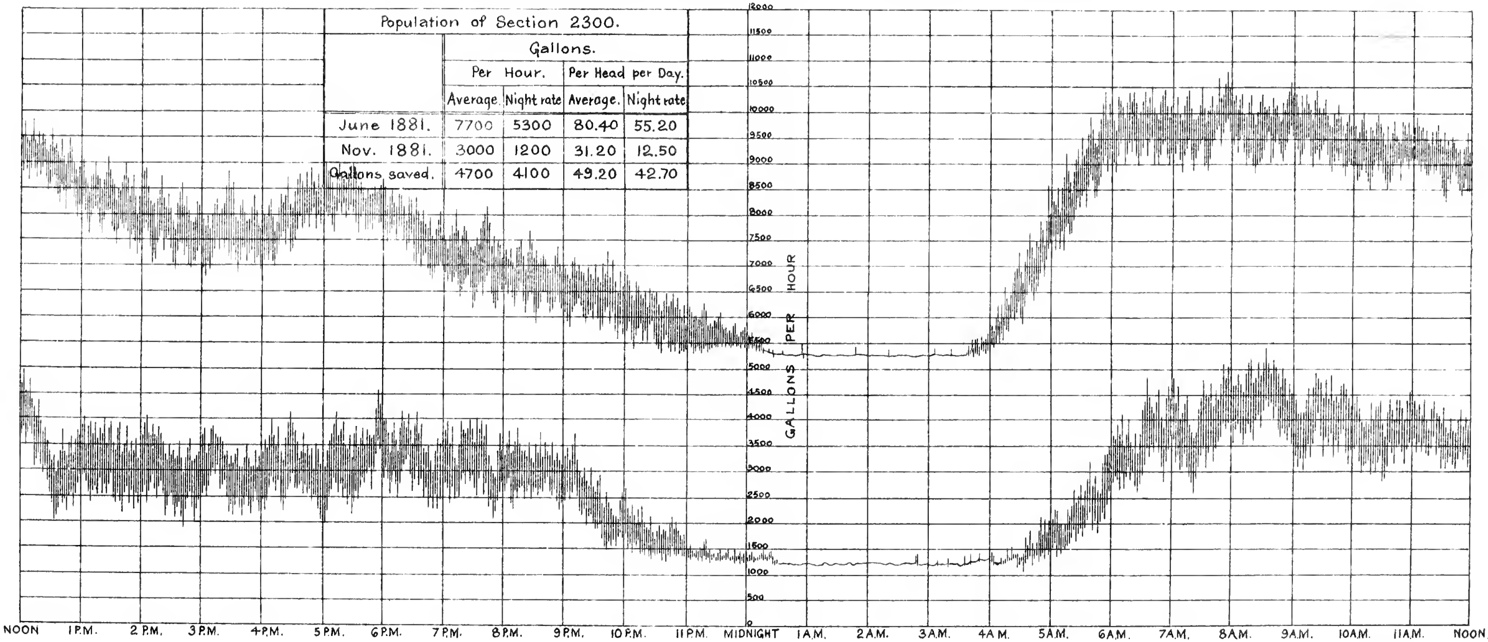
WASTE IN BOSTON AND OTHER CITIES.

With a very few exceptions the annual reports of the water departments throughout the country contain one or more pages devoted to the subject of waste of water and the best means for its prevention.

The following table, giving the population, consumption and other statistics in regard to the water supplies of several American and European cities, shows the great difference which exists in the amount consumed per capita under different systems of supply :

WASTE WATER METER DIAGRAMS SHOWING RESULTS OF INSPECTION IN SECTION 12.

PLATE 5.



Population of Section 2300.

	Gallons.			
	Per Hour.		Per Head per Day.	
	Average.	Night rate	Average.	Night rate
June 1881.	7700	5300	80.40	55.20
Nov. 1881.	3000	1200	31.20	12.50
Gallons saved.	4700	4100	49.20	42.70

AMERICAN CITIES.	Year.	Population.	Average daily consumption. Gallons.	Gallons per head per day.	No. of services.	No. of meters.	Miles of pipes.
Fall River	1881.	49,430	1,448,247	30.1	2,906	1,780	52.9
Providence	" .	102,500	3,716,937	36.3	9,780	4,816	.....
Lowell	1880.	59,485	2,252,197	37.9	5,480	708	63
Cambridge	1881.	52,880	2,472,108	46.7	7,523	157	.....
Brooklyn	1880.	566,689	30,744,590	54.2	59,880	1,085	351
Philadelphia	" .	847,542	57,707,082	68.1	....	......	746
St. Louis	1879.	346,000	24,958,000	72.1	19,000	......	199.6
Cincinnati	1880.	256,708	19,476,739	75.9	23,627	863	189
New York	" .	1,206,590	95,000,000	78.7	80,000	5,500	510
Boston	1881.	416,000	38,214,900	92	....	2,263	480
Chicago	1880.	503,304	57,384,376	114	67,949	2,113	455
Detroit	1881.	118,000	17,926,377	151.9	21,976	......	220.5
European Cities.							
Liverpool	1880.	703,000	....	27.0	....	.....	.....
Dublin	" .	246,300	....	45.6	....	......	.....
Edinburg	" .	304,000	....	48	....	......	....
Glasgow	" .	760,000	....	60	....	......	.. .
Hull	" .	150,000	....	39.2	....	......	....
Leeds	" .	312,000	....	27.9	....	......	....
Manchester	" .	900,000	....	24 0	....	......	.. .
Sheffield	" .	300,000	....	21.6	....	......	.....
Birmingham	" .	500,000	....	30	....	......	.....
Blackburn	" .	100,000	....	30	....	......	.....
Paris	" .	2,100,000	....	50.2	....	......	.....
Hamburg	" .	500,000	....	46.0	....	.....	....

In Providence and Fall River the use of water meters is very general: in Cambridge the street mains, service pipes and house plumbing are very carefully inspected, while in Chicago, Detroit, Cincinnati and Boston no stringent regulations are in force.

Measurements of the consumption between the hours of 1 and 4 A. M., when the legitimate use of water should be small, furnish very convincing proof of the waste of water.

The following table exhibits the results of some such measurements in different places:

	Date.	Rate in gallons per head per day.	Percentage of daily water
St. Louis	Jan. 1879.	71.5	85
" "	March, 1879.	51	78
Cambridge	Nov. 12 to Dec. 1, 1878.		41
"	" 1881.	15.5	37
Fall River	Feb. 4 to 8. 1878.	20	67
" "	July 16 to 20, 1878.	24	55
Boston—Cochituate Works	Jan. 22, 1879.	99	90
" Mystic "	" " "	104	96
" Cochituate "	April, "	55	69
" Mystic "	" 7 to 14, 1879.		76
" Cochituate "	Feb 4 to 14, 1880.	89	85
" " "	April 10 to 15, 1882.	73	77

In cities where all of the water supply must be raised by machinery before it can be used, the cost of pumping the wasted water becomes a large item of expense.

In the city of Chicago during the year 1880 the daily waste, assuming a legitimate use of 50 gallons per head, was 32,000,000 gallons. The yearly cost of the fuel required to pump this was $39,000.

Cincinnati, during the same year, wasted 6,641,300 gallons daily and expended $18,000 for fuel to pump the same.

In Detroit, during the year 1881, the total cost for fuel was $45 per day, of which two-thirds, $30 per day or $10,950 per annum, were expended in pumping waste water.

QUANTITY NECESSARY FOR AN AMPLE SUPPLY.

In 1838 it was stated in a report on the proposed supply for Boston that 28.5 gallons were considered as sufficient, as that appeared to be "the largest quantity furnished to any city which is subject for any portion of the year to the influence of a cold climate, or where the habits of life are of 'British origin.'"

This may be taken as a fair estimate of the ideas which then prevailed, but the experience of the forty-four years which have elapsed since that time has proved the practical inadequacy of that amount to meet the extravagant demands of the American people.

Taking into consideration the actual consumption of the large cities, American engineers have gradually increased their estimates of the quantity necessary for an adequate supply, until at the present time 60 and 70 gallons per head are provided for in building new works.

A few statements and opinions in regard to the quantity required for domestic and manufacturing uses may be of aid in making an estimate on this subject.

The experiments in the Charlestown district showed that after two inspections the daily consumption of the district was but 37.7 gallons per head, although the night rate had not been reduced below 15.8 gallons, of which probably 10 or 12 gallons were wasted.

During the past three months experimental meters have been attached to different classes of dwellings throughout the city of Boston for the purpose of ascertaining the actual quantity used for domestic purposes.

The results obtained may be summarized as follows:

The average daily consumption per head of 2,000 people was 52 gallons. The average consumption of one half of the number was 27.7 gallons each, while of the other half it was 77.5 gallons. Six adjoining houses on Dover street gave respectively daily average consumptions of 45, 132, 33, 307, 118 and 445 gallons per occupant. Two tenement houses on Athens street, which were unprovided with water-closets, the only fixtures being sinks in the kitchens, consumed respectively 16 and 177 gallons per occupant. There was no reason why there should have been any great variation in these quantities, yet we find, in three instances, one taker using ten gallons while his neighbor was satisfied with one.

The daily average consumption of one-quarter of the total number supplied was but 17.2 gallons per head.

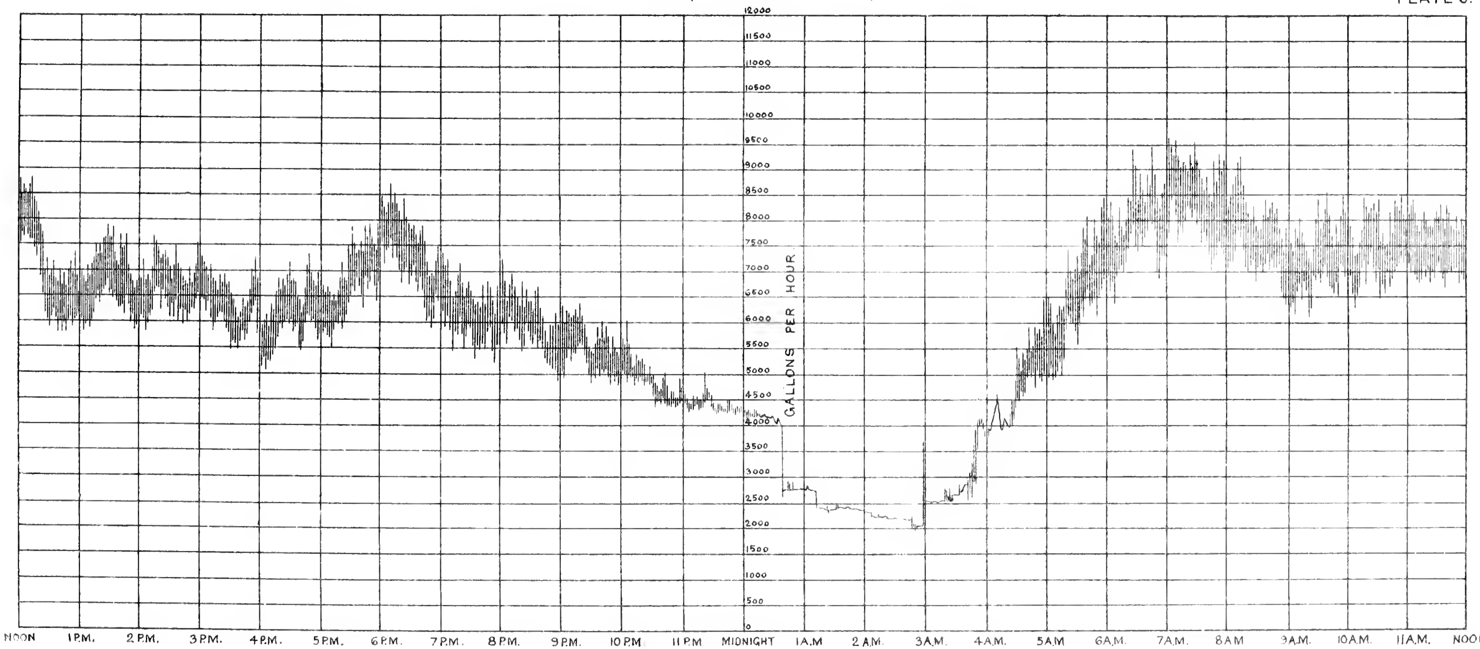
In the city of Worcester, in the year 1875, the average consumption for domestic purposes, of 690 persons, was thirteen gallons per head, as ascertained by meter measurement. A portion of these were not provided with water-closet supplies.

Joseph Parry, C. E., assistant engineer on the Liverpool Water-Works, in his book on "Water,"* estimates that "a total rate of 30 gallons per

* Water, its composition, collection and distribution. J. Parry, C. E., 1881.

PLATE 6.

WASTE WATER METER DIAGRAMS SHOWING RESULT OF CLOSING ONE SERVICE PIPE. SECTION 12.



head per day is a liberal allowance for all domestic, trade, sanitary and public purposes (including waste), of a town in which there are considerable but not exceptional manufacturing industries, and in which water-closets are in general use." This is an estimate based upon English habits and modes of supply.

Taking into consideration the above statements, in connection with the actual consumption of cities where the meter system or careful inspection prevails, I am of the opinion that 27 gallons per head will give an ample supply for domestic use, in which should be included the quantity required for stables and such stores and shops as are required to meet the ordinary needs of a community.

The requirements for manufacturing and business purposes vary largely in different cities. Where the requirements for shipping and railroad purposes are large, and where the consumption during the day hours is largely increased by the consumers whose residences are in suburban cities or towns, the demands of a metropolitan character are large.

On the Cochituate Works the amount used for manufacturing and business purposes during the year 1880 was about 20 gallons per head, of which 10 gallons were measured by meters. As it is probable that one-half of the unmetered portion was wasted, the legitimate demands for business and manufacturing uses in Boston are about 15 gallons per head.

Adding to the amounts required for domestic, manufacturing and business uses, eight gallons for public uses, and the waste which must always exist to a limited extent, there is obtained a total of 50 gallons per head as the amount sufficient to provide for all the demands of the largest cities of the country.

METHODS OF PREVENTING WASTE.

Three principal methods of controlling or preventing waste are at the present time prominently before the public, viz.: House to house inspection; the application of water meters to all of the service pipes; and the use of waste detectors, among which the Deacon system of waste prevention is the most generally used.

House to house inspection has been, or is at the present time, used with greater or less success in most American cities.

If faithfully carried out, this system can be made to furnish excellent results. By its use, the consumption of Boston was reduced from 88 gallons to 66 gallons per inhabitant between the years 1864 and 1865.

The city of Cambridge controls its supply by this method, so that its consumption is but 46.7 gallons per head, of which 10 gallons are used for manufacturing purposes and street watering.

This method, however, fails to detect many cases of hidden waste, and the cost of carrying it out is very much increased by the necessity of inspecting many buildings where the fixtures are in repair. The careful owner or tenant, on whose premises no waste exists, is subjected to the same annoyance as his more careless neighbor: a feature of the system which has always been one of the greatest hindrances to its success. Further, the system gives no check upon the work of the inspectors, and the amount of the saving effected is unknown except in a very general manner.

The citizens of Providence, Fall River and Pawtucket at the inception of their water-works adopted the second method, viz.: the use of water-meters. Providence consumes 36.3 gallons per head of population; Fall River, 30.1 gallons; Providence, with 9,780 service pipes, has 4,816 meters; in Fall River 60 per cent. of the services are metered. The use of meters is condemned by some authorities on sanitary grounds, for the reason that the people, especially the poorer classes, if obliged to pay for all water used, will restrict their use to a point prejudicial to the public health, but this objection is obviated to a great extent by the plan adopted in at least some of the cities where meters are used, of obliging all takers to pay a certain minimum rate, based upon a reasonable allowance for domestic needs. The underground waste, saturating the ground beneath our dwellings with moisture and the constant dribbling of innumerable streams from defective ball-cocks and water-closets, are not conducive to the public health. Two gallons of water properly used would be more efficacious for flushing purposes than 200 gallons as often applied.

Where the meter system can be adopted with the building of the works there is no doubt but that it furnishes the most satisfactory means of regulating the use and cost of water, but upon old works there are many objections to its use.

The third method which has been fully described in previous pages may be called a modification or improvement of the first.

By the use of waste-water meters, and the system of inspection connected therewith, the exact location and amount of the waste is definitely determined.

The inspections being made in the night, are made when the chances for discovererring waste are most favorable. The only premises visited by the day inspector are those where there is known to be waste. Only about one fourth of the takers in the Charlestown district were visited by this inspector, and if the system were continued in operation the proportion would be still smaller. In Glasgow the inspection necessitates visits to about one fifth of the population. In Liverpool the proportion is one tenth.

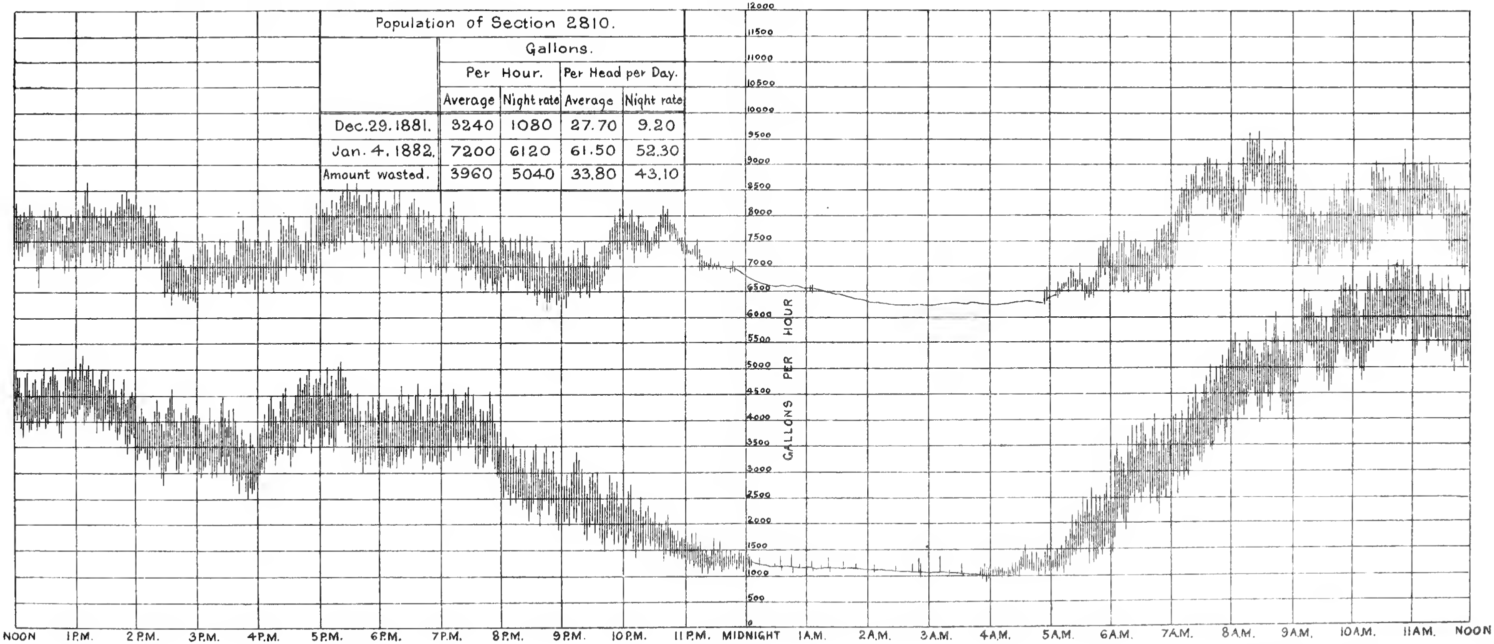
Under the usual method of house to house inspection, the time of the inspectors is spent equally upon all districts whether wasting large or small quantities, while under the waste-water meter system, the most wasteful districts receive the greater share of attention. As an example, Sec. 7 of the Charlestown district required 20 nights' work, while Sec. 11 required but 5; and this fact would be illustrated more clearly after the first two or three inspections had been made.

Neither house to house inspection, nor the Deacon system, can be made thoroughly effective unless aided by the enforcement of ordinances requiring the plumbing to be done in accordance with proper regulations and under inspection, and by prescribing the class and quality of water fixtures that may be used.

Providence, New York, Brooklyn and other American cities license their plumbers, and to a certain extent inspect the fixtures used; but in English cities the ordinances and regulations are much more rigid than those in this country. Liverpool, Manchester, Glasgow, and other English cities test and stamp all of the water fittings used. In Glasgow,

WASTE WATER METER DIAGRAMS SHOWING AMOUNT WASTED TO PREVENT FREEZING OF SERVICE PIPES – SECTION 1.

PLATE 7.



Population of Section 2810.

	Gallons. Per Hour. Average	Gallons. Per Hour. Night rate	Gallons. Per Head per Day. Average	Gallons. Per Head per Day. Night rate
Dec. 29. 1881.	3240	1080	27.70	9.20
Jan. 4. 1882.	7200	6120	61.50	52.30
Amount wasted.	3960	5040	33.80	43.10

during the year 1877, when this plan was first adopted, of 4,369 fittings examined, 14.6 per cent. were rejected, while in 1880, of 27,517 examined, but 3.92 per cent. were rejected. In the latter city certain varieties of fittings are proscribed. When any of these are found wasting water twice during three months, they are removed, and their use is not allowed at all in new premises.

All cisterns are provided with overflow pipes, which are brought outside the building or made to discharge inside where they can be seen. The service pipes, except in special cases, are required to be of lead, and their weight is prescribed. No pipe or fitting can be covered until inspected, to see that it conforms to the regulations.

Water-closets and urinals are not allowed to be supplied direct from a service pipe, but must be supplied from cisterns, so constructed that in water-closets not more than two gallons can be used at a single flush, and in urinals not more than 1½ gallons, and so that they cannot be made to flow continuously either by intention or neglect.

The adoption of the above, or similar regulations in American cities, while not in the least curtailing the legitimate use of water, would be the means of preventing a very large proportion of the present enormous amount of willful and useless waste. The cold weather waste can never be completely stopped until property owners are obliged to arrange their plumbing so that the water can be completely drawn from the pipes when liable to freeze.

By the use of meters it can be largely reduced, as the waste would be reduced to the minimum amount required to prevent the pipes from freezing, and it would become a question to the water taker whether it was economy to waste water or remodel his fixtures.

Each of the three systems described have their special uses; and, in considering the expediency of their use in different cities, the different conditions of supply must be regarded.

The introduction of the meter system upon old works can seldom be accomplished except at a very large expense both to the city and the water takers; but for new works, and for business and manufacturing uses in every city, they furnish the most satisfactory method of controlling the supply.

For domestic use, where the service pipes are provided with sidewalk shut-offs, the Deacon system will give the best results with the least expense.

If there are no shut-offs in the sidewalks, the complete application of the Deacon system cannot be accomplished except at a large expense, but in such cases the meters can be used to advantage in connection with house to house inspection to give the results obtained in different sections.

It is not probable that the results obtained in Liverpool can be duplicated in this country, as the conditions of supply are not the same; but opportunity is offered to effect a great saving in almost every city of magnitude in the country.

Finally, in view of the millions of dollars which have been and are now being expended upon the water supplies of American cities solely for the purpose of supplying water to be wasted, and in view of the millions which will unavoidably be required in the not far distant future, unless

some means are taken to reduce the present consumption to within reasonable limits, it becomes a question of great importance, not only for the engineers and water officials, but also for the general public to consider, whether the time has not arrived when some more stringent measures should be taken to reduce the waste of water and to confine the use of the same within reasonable limits.

SILT MOVEMENT BY THE MISSISSIPPI—ITS VOLUME, CAUSE AND CONDITIONS.

By Robt. E. McMath, Member of the Engineers' Club of St. Louis.

The volume of solid matter borne by rivers, the mode of its conveyance and the conditions of deposit and removal are topics of interest to the engineer who has to do with works at the margin or in the bed of silti conveying streams. These topics have special interest at the present time, because of their bearing upon the improvement of the Mississippi.

I propose to state in brief the result of my personal study of observations made under my immediate charge, as assistant to Gen. J. H. Simpson, U. S. Engineers, adding data from other sources when needed to complete or support a conclusion.

The observations were made under favorable conditions, using apparatul of improved design. The locality chosen was a few hundred feet above the foot of Grand avenue, St. Louis, where the width and sectional area of the river approximated a mean value.

Samples of 100 grammes each were taken daily, 1 foot below surface, at mid depth, and 1 foot above bottom, at positions dividing the width into 8 parts—making 23 daily samples. The daily samples from each position were combined for periods of 6 and 3 days, as shown in the table on the opposite page.

Perhaps a better apprehension of the amount of turbidity may be gained by remembering that 1,000 parts in 1,000,000 by weight is very nearly one ounce of solid matter to a cubic foot of water. To reduce to ounces per cubic foot cut off three decimal places in the column headed "sediment."

Specimens were weighed dry after continued exposure to a temperature of 180° F. A cubic yard of compacted sediment was taken at 1.6 tons (3,200 lbs.).

During the 87 days between March 31 and June 25, 1879, 62,363,000 cubic yards of solid matter passed the observation station in suspension. A quantity sufficient to cover a square mile to a depth of $60\frac{4}{10}$ feet.

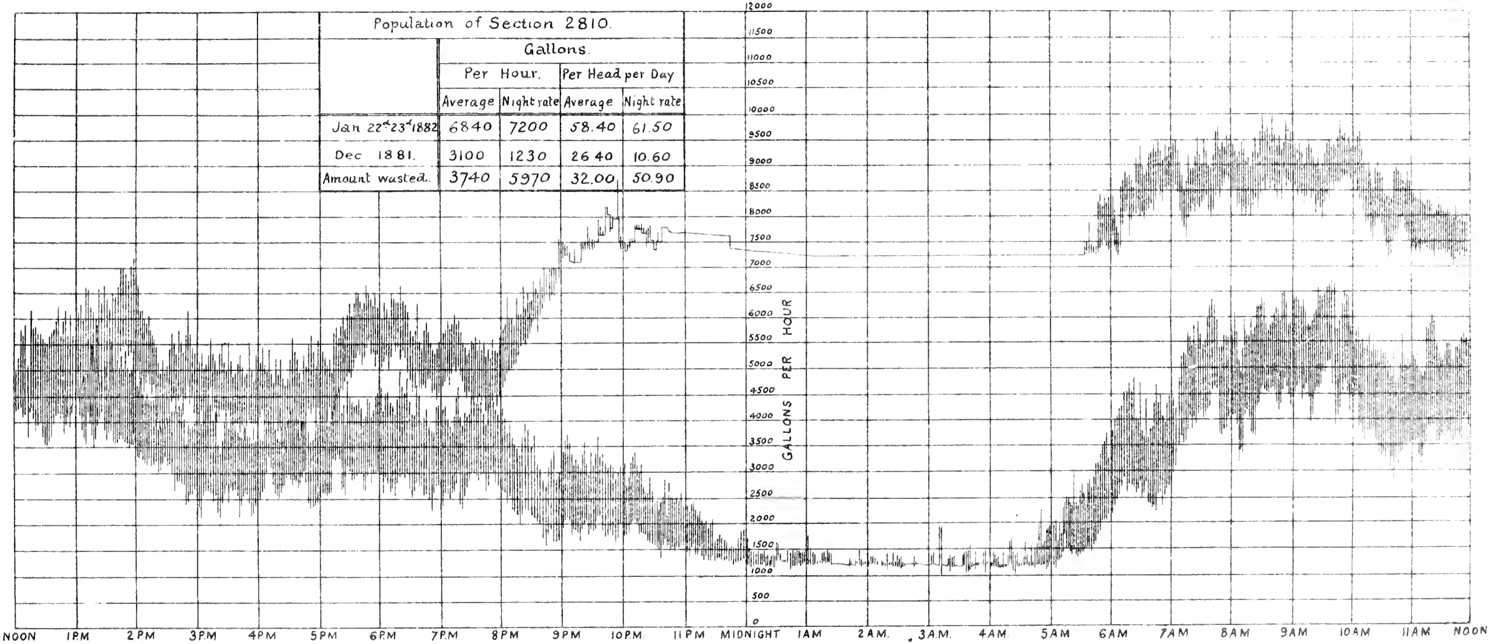
Observations were made the same season by Maj. C. R. Suter to determine the volume of solid matter borne by the Missouri River near St. Charles. The general results have been reported as

Mean volume for the year 1879	475,457	cubic yards per day.	
" " " June and July	1,755,423	" " " "	
Maximum " on July 3	4,113,600	" " " "	

The stage at St. Louis for June ranged from 13.2 to 21.0: mean, 16.6. For July the range was 21.0 to 16.1; mean, 18.0. The "danger line," or

WASTE WATER METER DIAGRAMS SHOWING AMOUNT WASTED TO PREVENT FREEZING OF SERVICE PIPES - SECTION I

PLATE 8.



Population of Section 2810.

	Gallons. Per Hour. Average	Gallons. Per Hour. Night rate	Gallons. Per Head per Day. Average	Gallons. Per Head per Day. Night rate
Jan 22d 23d 1882	6840	7200	58.40	61.50
Dec 1881.	3100	1230	26.40	10.60
Amount wasted.	3740	5970	32.00	50.90

beginning of damaging overflow, corresponds to a stage of 30 feet. Extreme known flood to 41.38.

The observations, therefore, do not include a flood or even what would be called a high stage.

Dates.	Stage.		Sediment Parts in 1,000,000.					Mean velocity of river, ft. per sec.	Quantity of sediment in cubic yds. per day.
			Mean of all stations.			Near sides.			
	Range.	Mean.	Surface.	Mid depth.	Bottom.	Mo. ordinate 281′.	Ill. ordinate 1291′.		
	Ft.	Ft.							
1879.									
Mar. 31-Apr. 5	11.0 12.5	11.9	533	493	581	1003	270	4.34	138,182
Apr. 7 " 12	12.3 17.3	14.5	1998	2363	2398	3100	1173	4.58	782,434
" 14 " 19	18.0 14.9	16.5	3601	3731	3809	4200	3400	6.13	1,555,646
" 21 " 26	14.0 12.9	13.4	1581	1657	1814	2190	1298	5.20	449,985
" 28 " 30	12.6 12.3	12.5	1509	1568	1577	2100	1017	4.93	396,585
May 1-May 3	12.2 11.2	12.1	1351	1377	1378	1825	951	4.56	349,903
" 5 " 7	11.8 11.6	11.7	996	1066	1096	1690	560	4.14	282,892
" 8 " 10	11.8 12.1	11.95	1332	1378	1456	1951	945	4.00	343,475
" 12 " 14	12.2 11.8	12.0	2014	2118	2166	2771	1605	4.14	508,521
" 15 " 17	11.75 11.8	11.8	2267	2449	2467	2948	1973	4.07	559,457
" 19 " 21	11.5 11.3	11.4	1408	1516	1639	2362	1082	4.12	360,335
" 22 " 24	11.4 11.5	11.25	1556	1685	1793	2432	1297	4.11	391,404
" 26 " 28	11.5 12.0	11.7	1226	1311	1646	2302	992	4.17	357,160
" 29 " 31	12.3 12.9	12.6	1055	1232	1250	2408	653	4.55	378,960
June 2-June 4	13.4 15.3	14.3	1274	1429	1530	3188	652	5.52	560,681
" 5 " 7	15.5 15.9	15.7	1863	2213	2327	3453	1216	5.81	932,666
" 9 " 11	16.5 16.0	16.3	1567	1791	2056	3103	1097	6.23	886,090
" 12 " 14	16.0 16.1	16.0	1553	1765	1948	2878	1165	5.86	839,490
" 16 " 18	16.3 16.4	16.3	2281	2596	2752	3245	2057	6.31	1,134,475
" 19 " 21	17.0 17.7	17.3	3347	3651	3818	3882	3693	6.93	1,656,553
" 23 " 25	17.9 17.5	17.8	4477	4796	4963	4425	4883	7.21	1,983,467

Observations for 250 days at Fulton, Tenn., made by the Mississippi River Commission, gave a maximum of 3,232,209 cubic yards on July 10, 1880. The aggregate for the period January 1 to October 8, 1880, was 217,728,125 cubic yards, or sufficient to cover a square mile to the depth of $210\frac{8}{10}$ feet. The minimum discharge for any day at Fulton was 136,458 cubic yards, confirming the minimum observed at St. Louis.

The comparatively small volume of sediment at low stages is of itself sufficient proof that important changes, by way of deposit in the bed, cannot occur at low stages except as a result of local movements.

Considering the moving mass as among the material resources of the engineer on one hand, or as a possible opposing force on the other, it ap-

pears from the foregoing figures that at one season the quantity is scant and the forces feeble, at another the quantity is enormous and the forces overpowering unless skillfully handled. It is readily seen how necessary to an intelligent dealing with the river is a thorough knowledge of how, when and why the silt movement occurs.

If one examines the material found in suspension he will discover that a considerable proportion is in a state of subdivision so minute that it separates from the water very slowly. The experiments of Col. Flad made in 1865 are in point. He found that of 1,000 parts of matter in suspension at the beginning of the experiment,

944.50 parts settled to the bottom in first 24 hours.
22.35 " " " " " " second 24 hours.
2.92 " " " " " " " 48 hours.
30.23 remained in suspension at end of 96 hours.

The practical problem of river engineering has little to do with this very fine matter. Its presence and transport is analogous to that of impalpable dust in the air and requires no comment.

Without drawing arbitrary lines of classification as to weight or size of particles transported, which may vary from impalpable dust to the rock fragment, occasionally rolled over by the current, we can recognize three grades or species of movement and material.

First. Some of the traveling material never loses contact with the bottom.

Second. Material which, though heavy and in grains of notable size, is detached for a time by some energetic impulse and describes a longer or shorter free path, moving in or with the surrounding water.

Third. Material which, once mingled with the water, remains in continuous suspension until it reaches the sea.

No measure of the first-grade movement has yet been satisfactorily made, being, so far as manifested by progress of sand waves, undistinguishable from movements of the second grade. It is probable that the ordinary impression of its amount is an exaggeration.

The muddy appearance of the river is mostly due to the fine or third-grade matter. The proportion of such matter present is in close accordance with the appearance. But appearances give slight clue to the more important second-grade movements below the surface, which are manifested to the ordinary observer only by their results in bars deposited or removed.

Recurring to the figures stated, at first thought the transportation of so great a mass seems to present an important dynamical question.

Mass transported is work done, and work absorbs force. Water is matter, and its transport in a running stream is work. We say readily that the force is gravity, the body falling.

A chip floating with the current is a solid body being transported; it is, however, but a representative of the volume of water it displaces, and its motion is due to the same cause. It is not moved by, but moves with the water. So far from its transport being at the expense of the stream, the quantity of motion (MV.) is increased by its presence. The like may be said if the solid be of the same density as water, and immersed at any point of the depth. The effect upon MV. is the true test; therefore, if a

pebble be thrown into a stream the quantity of motion will be increased or diminished, as the direction of its projection is with or against the current. It is thus seen that transportation in a running stream is an incident to the state of suspension, immersion, or flotation. The inquiry that interests us turns to the cause of suspension; or how bodies heavier than water can be sustained clear of the bottom for an indefinite time. If heavy bodies, when cast into the stream, always reached the bottom after an interval of time and distance, and remained there, the possible movement past any station would be measured by the contributions of matter from outside sources within a very moderate distance. But, since the quantity moving and the supply from local sources do not correspond, we are compelled to conclude, that a force exists within the stream capable of resisting the descent of injected solid bodies, so that transport of contributions is continuous, or else the force is capable of the more serious work of detaching such solids from the bed, or banks, and projecting them upwards even to the surface, or laterally to considerable distances. The facts demonstrate the existence of such an upward and lateral force.

Three hypotheses have been suggested to account for or define the force.

First Hypothesis. It is due to the differences of velocity with which contiguous layers or fillets of fluid move, the submerged or floating body being impelled toward the fillet of greatest velocity.

Second Hypothesis. It is due to a general vertical component of the stream's motion, by which the water at the bottom is continually being brought to the surface.

Third Hypothesis. The power of erosion and suspension is due to the irregular movements, which arise in all bodies of moving water, and are in complex proportion to the velocity of the stream and the character and condition, or, as we may say, to the accidents of the bed.

To consider these hypotheses would extend this paper beyond due limits. It is sufficient to say that the gradation of velocities in a vertical direction, so as to present a curve of velocity regularly increasing from bottom to surface, is not verified by observation. As the velocities in a vertical approach a regular curve silt conveyance ceases; and conversely, as silt movements increase the vertical curve of velocities becomes an irregularly waving or serrated line. I therefore reject the first hypothesis.

The second hypothesis, of a general upward tendency of water and immersed bodies, implies a converse proposition of a downward movement in equal volume. Since movements in opposite directions cannot coexist in place and time, a division of the stream into ascending and descending areas is needed, or the movements must alternate at short intervals. In either case, the facts would come within the range of observation. Failure to detect the supposed movement in the general form required by the hypothesis leads to its rejection.

The third hypothesis differs from the second by a prefix only. It attributes suspension to irregularities of motion. We can conceive a stream flowing in a polished bed with a gliding, straight-forward movement in every part, and such an idea underlies theoretical discussions in

which fillets or layers are imagined. In real channels the roughness of bottom is sufficient to secure a thorough mingling of the waters; but the interior movements will be too feeble to sustain solid matter if the bed be smooth and the area large.

Irregular motions manifest themselves in boils. eddies and whirls. That boils bring mud as well as water to the surface is a matter of common observation. At a position where the normal quantity of sediment was. at surface 2.278, mid depth 2.427, and one foot above bottom 2.880 ounces per cubic foot. samples taken from a boil gave at surface 3.006. at 15 feet depth 3.755. and at 37 feet depth (one foot above bottom) 2.706 ounces to a cubic foot. Of course it is not certain that any except the surface specimen was taken from the heart of the boil. for the rising path must necessarily be guessed at in attempts to reach it at lower depths.

A boil originates at the bottom and may be caused by any obstruction which deflects the impinging current.

The irregularities of bottom which may deflect currents are numberless. and the deflections may be in all possible forward directions. and the impulses may have any degree of intensity within the limit of the stream's velocity. Of the whole number it is certain but a small proportion will have a direction and intensity that will bring them to the surface; but the number of boils appearing at the surface is probably in proportion to that of the unseen. so their visible increase may be taken as marking an increase of the forces and motions below.

In bringing forward this hypothesis nothing new is involved. for all more or less distinctly admit that the irregular motions share in the work. They who hold the theory of relative velocity in any form are forced to ascribe to the whirls and boils the mingling of material equal in size but differing in density, or of different sized grains of equal density at a given level; also the suspension of all matter whose density is greater than water above the axis of greatest velocity. This third hypothesis goes but one step further in ascribing to the irregular movements the whole work of suspension, upon the ground that a cause. known to exist wherever the fact to be accounted for occurs, and admitted to be efficient. must be considered the sole cause unless a coworking agency is known, or the cause is insufficient to produce the observed result. Observation readily detects whirls, boils and eddies in the act of bringing water and suspended material from the bottom to the surface. and laterally from the side to the centre of the river. Observation has never detected any other cause incident to the flow of streams which produced these effects.

Once impressed by the fact that a body of moving water is an involved network of irregular movements or jets (so to speak), a person can easily understand that the power to separate solids from the bed and maintain them in suspension is dependent upon the direction and energy of the jets. The jets have their origin at irregularities of the bed, by which parts of the stream are deflected from their regular forward course. Their number and energy will ordinarily increase or diminish with the velocity of the stream. So, in a restricted sense, we may say that power of suspension varies with the velocity; but, since the relation is not

direct, being through an intermediate agency, there are many exceptions to the apparently general rule that a quickened current takes up an additional load, and its converse that a check of the current will determine a deposit. If, for instance, the stream pours over a reef, with gentle backward and steep forward slope, there is in approaching the crest a quickening of velocity without increase of burden, for the crest is not worn down. In passing the crest the sensibly horizontal movement becomes a plunge, the forward component of movement is materially reduced, the vertical is greatly increased, the deflected current impinges upon the bottom and does work in excavating a deep hole, expending upon that work a portion of its force. The reflected current returns toward the surface with an increased load of sediment which may be borne to a considerable distance before the subsidence of the agitations caused by the plunge will allow it to fall to the bottom. We thus see that the lessening of silt burden depends upon the manner of the slackening, rather than on the fact of slackened current. If the motion is diminished because of increased area without abrupt change of direction, deposit will ensue, but if the slackening be the effect of change in direction increased irregular motion is the first result, and with it increase of suspending power.

Erosion at the origin of a jet is the natural consequence of impact and reflection of currents if the bottom be yielding. Detached matter is kept in suspension by the interfering currents through a succession of impulses. The earlier and rising part of a jet, whether it be a mass projected by a momentary or a stream by a continuous impulse, is concentrated and energetic; later it becomes diffused and weak; therefore the resultant of impulses originating at the bottom is always upward.

We have now reached a more definite idea of the cause of suspension. It is a result of work done upon the bed and banks. The internal movements which prolong suspension are another form of work. Work may be done by a body whose motion is diminishing or increasing. It is, therefore, well to keep in mind the stricter definition of the cause of suspension, and consider it as associated with, rather than caused by, velocity. Failure to observe the distinction will often lead to unsound reasoning, and to disappointment in results realized when projects are executed.

We have seen that transportation of silt (up to the point of impaired fluidity) is not at the expense of the stream's motion. The work of erosion and suspension is done by the stream, whose velocity must be diminished compared with flow under a like head in a smooth channel, but if the now yielding bed should suddenly become rigid the same, or even greater, force would be expended upon the obstructing roughness. Therefore, though suspension consumes a part of the stream's force, the velocity is not necessarily lessened beyond what it would be in the only alternative condition that can be considered, a rigid bed equally rough.

The burden of suspended matter is not the same for a given velocity when found at different places, nor at the same place at different times, because irregular movements increase or diminish under local and temporary conditions. The maximum load was found in nearly every observation several hundred feet nearer the Missouri shore than the line of greatest velocity; therefore equal velocities on either side of that line

were attended by dissimilar silt burdens. It may be well to add, that in any river section the profiles of velocity and depths follow each other so closely that one may be taken as the reflection of the other: hence supposed variation of suspension with depth cannot account for the difference observed.

In attributing suspension of solid matter to irregular internal motions, advance is made from the somewhat vague idea of unsteady motion or pulsation of currents suggested by some observers to a more definite interlacing of stream lines, whose resultant is an upward thrust.

In a great river the inequalities of the bed act an important part in developing scouring power at the bed, and sustaining power throughout the extended mass of considerable depth and width. But this statement must not be understood as implying that roughness of channel would facilitate the transport of sewage matter. In the limited channel of a sewer or water conduit, the intermingling required to maintain suspension is sufficiently provided by contact with the comparatively large wet surface. Removal of deposits requires additional force.

Having now shown the volume approximately, and the immediate cause of silt movements, we are prepared to consider the consequences of variation in this cause, or in the ability of the river to carry its burden.

Clearly this variation may be due to season, comparing high and low stage, or to locality, comparing areas and form of cross section, also to the varying inclination of surface.

This division of the subject is directly practical, for a man's judgment, as to the merits of rival proposed methods of dealing with the Mississippi, will turn according as he accepts or rejects the following statements of fact, and the legitimate inferences from them.

"The History of the St. Louis Bridge," by our fellow member, Prof. C. M. Woodward, records the fact that the river bed at the bridge site deepened in time of high water. The engineers, who have been engaged at Horsetail Bar, 10 miles below the bridge, have repeatedly stated that the bottom there rises during the flood and is cut out by the falling river.

These apparently conflicting statements put us upon the inquiry why opposite results should attend a high stage at the two localities ?

The known variation of bed at Horsetail is ten feet, measured in the channel. That is to say, a channel 4 feet deep was found at lowest fall and winter stage. A moderate rise of 20 feet following, the river after falling 6 feet afforded a channel depth of but 8 feet, whereas $4 + 20 - 6 = 18$, a difference of 10 feet. The former channel was not only obliterated, but every square yard of area in a limited length of river, which was covered by water at the low stage and all the area then dry, was filled in during the rise to a height of at least 6 feet above the low-water surface of the preceding season.

The observed vertical variation of bed at the bridge site is said to have been 15 feet.

Observations made in 1878–1879 at a series of sections in front of St. Louis and below the bridge gave the following results :

Section.	Width.	Change in Area. Sept. 17 to Mar. 31.	Mar. 31 to May 10.	Sept. 17 to May 10.	Change in Mean Depth. Sept. 17 to Mar. 31.	Mar. 31 to May 10.	Sept. 17 to May 10.
	feet.	fill sq. ft.	fill sq. ft.	fill sq. ft.	ft.	ft.	ft.
Pine st...........	1,604	2,583	2,255	4,838	—1.61	—1.41	—3.02
Chestnut st......	1,609	5,141	575	5,716	—3.45	—0.35	—3.80
Market "	1,650	3,306	1,091	4,397	—2.00	—0.61	—2.61
Walnut "	1,744	1,143	2,920	4,063	—0.65	—1.62	—2.27
Elm "	1,815	4,119	4,082	8,201	—2.26	—2.23	—4.49
Myrtle "	1,885	5,523	2,622	8,145	—2.91	—1.40	—3.31
Spruce "	1,942	4,520	4,546	9,066	—2.27	—2.32	—4.59
Almond "	1,982	3,695	2,907	6,602	—1.49	—1.46	—2.95
Poplar "	2,032	4,523	547	5,070	—2.17	—0.26	—2.43
Plum "	2,033	3,930	1,291	5,221	—1.69	—0.63	—2.32
Cedar "	1,958	5,792	— 327	5,465	—2.96	+0.17	—2.79
Mulberry "	1,893	1,978	5,206	7,184	—0.86	—3.06	—3.92
Pittsburg Dike ...	1,547	3,180	8,268	11,448	—2.02	—5.18	—7.20
Means..........	1,822	3,802	2,768	6,578	—2.02	—1.56	—3.58

The stage, from September 1 to May 31, was by mean of 10-day periods:

Days.	1878. Sept.	Oct.	Nov.	Dec.	1879. Jan.	Feb.	Mar.	Apr.	May.
1—10.........	10.9′	9.6′	9.8′	9.4′	8.0′	9.3′	7.6′	12.2′	11.9′
11—20.........	9.7′	10.0′	9.5′	8.2′	8.6′	8.9′	11.3′	16.4′	11.0′
21—30-1........	9.2′	10.7′	9.2′	6.3′	9.2′	7.5′	11.4′	13.1′	11.0′

The fill which occurred between September 17 and March 31 must have been made when the stage was low and the water comparatively clear. If the fill was interrupted by the rise in April, which reached an 18-foot stage, it was resumed and the apparent result is a continuous fill up to May 10. The reported scour at the bridge by a flood involves a converse proposition of fill at some other stage, else the section would sink to bed rock and become permanent: this inference is fully supported by the behavior of the sections below the bridge, stated above.

The area of cross section at Pine street was 41,000 square feet, stage 9 feet; the area added by a 30-foot stage would be 38,000 square feet; total, 79,000 square feet. At Horsetail the river was 4,800 feet wide, and area at 9-foot stage less than 20,000 feet, there being scant 6 feet in the channel. The area which would be added by a 30-foot stage equals 103,000 square feet; total, 123,000. Comparing areas at the two localities we have for 9-foot stage at Pine street 41,000 square feet, at Horsetail 20,000; 30 foot stage at Pine street, 79,000 square feet, at Horsetail 123,000. Since mean velocities are inversely as the areas it follows that the current at low stage must be slack in front of St. Louis and swift at Horsetail; at high stage, on the other hand, it must be swift at St. Louis and comparatively slack at Horsetail; or else alternate fills and scours must occur at the two localities to equalize areas. Since the cause of suspension commonly varies with the velocity, fills and scours will occur, and a partial compensation of areas be made. Considering the material by which the compensation is effected, we see that material scoured by the flood current from the narrow section passes to the succeeding wide reach and is there

deposited: at a low stage the area in the wide reach becomes deficient, velocity increases and scour ensues: the material is borne only to the succeeding sluggish pool.

I have presented the facts in front of St. Louis and at Horsetail at large because they are, when taken together, typical of what does and must take place elsewhere wherever like contrasting conditions occur.

The movement of coarse, heavy material is now seen to be a succession of steps: out of the pool into the wide reach in time of flood, and out of the wide reach into the succeeding pool during the subsequent low stage, with a period of rest intervening for individual particles, but a continuity of movement in the aggregate.

It has been thought by some that deposit cannot occur if the velocity be greater than that usually believed to be capable of moving a given material. And, since the velocity everywhere at high stages exceeds the supposed limit required by sand, it is argued that flood time is a period of universal scour, and the deposits observed to occur must be made at the turn and during the falling stage. In answer, it may be said that the change of velocity at transition from rising to falling stage is much less than occurs from variation of section at succeeding localities at high and low stages indifferently. But it will more effectually dispose of this idea to ask where does the material eroded by a flood go to, if scour be general and several feet in depth? And, if fill be general at falling stage, where does the material come from? The alternate movement between pool and shoal alone meets this difficulty about source and storage of material.

Summing up the results of the study it appears:

1st. The cause of suspension is found in the irregularities of motion resulting from work done by the stream upon the bed and banks. These irregularities in general vary with the velocity of current and accidents of bed and bank.

2d. Variation in the power of suspension as the water passes along its course is largely due to relative values of sectional area, and these depend chiefly upon width and form of section.

3d. Scour and deposit are, under the conditions now existing in the Mississippi, local, not general occurrences, which alternate at a given locality as the river passes from one extreme of stage or volume to the other.

To enforce these conclusions I add this final fact: The volume of matter in suspension which passed the foot of Bullerton towhead between November 13, 1879, and January 3, 1880, was 702,000,000 cubic feet. The amount which passed Fulton (nine miles below) during the same time was 1,011,000,000 cubic feet; wherefore the difference, 1,011,000,000 — 702,000,000 = 309,000,000, must have been obtained by erosion of the intermediate bed and banks. Between March 6, 1880, and April 11, the volumes were: Past Bullerton, 907,000,000 cubic feet; past Fulton, 832,000,000 cubic feet, 75,000,000 cubic feet being deposited in the intermediate bed.

Bullerton is at the foot of a wide shoal reach. Fulton is at a narrow part of the river. During the first period the river rose 26.6 feet, during the second it fell 6 feet.

The results, it will be observed, are similar to those at St. Louis and Horsetail, but the measured quantities show the variation in suspension directly. The succession of contrasting local conditions is reversed, the pool following the shoal.

Variation of width and form of section have appeared to be important factors in determining the alternate movement of heavy material from pool to shoal, and from shoal to pool, as stage or volume increases and diminishes. It is also certain that an indefinite volume of heavy material is brought into the bed of the river every year by tributaries, and a like volume must be discharged at the mouth, in order that a stable or permanent condition may be maintained. Under the alternations, arising from varying width, the river, taking its whole length, is encumbered with the accumulated detritus of a number of years, all traveling. If a summation be made in cubic units of the whole mass moved in a given time, it will exceed the actual discharge of solid matter manifold, but if it be measured as mass moved over space, the summation will be equal to the movement of the incoming material from the point of entrance to the sea.

If we consider that the material passing a given point can travel but a short distance in a day at the farthest, we see that the sum total of moving material must be enormous. For instance, the summation on July 10, 1880, must have been several hundred times the quantity observed at Fulton, 3,232,209 cubic yards, or a total measured by hundreds of millions of cubic yards.

Considering the movement in time of flood we must remember that the arrest of motion due to variation of section is not of the whole mass, but of the coarser part only, and the arrest of this part need not be an absolute stoppage, in the sense that no coarse material passes the wide reach during the period of accumulation. If a column of men be marching along a street at an unequal rate, the centre moving more slowly than the extremes, the advance files will widen the intervals, and the rear will at the same time close in upon the slower centre. This centre illustrates the wide places in time of flood. If again the front and rear slacken step and the centre hastens, the massing will be in front, and intervals will increase at the centre and toward the rear. The illustration now becomes parallel to motion from wide to narrow sections at low stages.

The changes from accumulation to waste (deposit to scour), therefore, do not imply a cessation of movement at any place or time, but may be accounted for by a varying rate of progress.

If the variation of width be suppressed by "regularization," one of the local complications of silt movements will be removed, the rate and volume will still vary with the motive forces. The movement of heavy bar-forming material is now continued during low stages, but in the regulated channel there will be no concentration of force to enable low stages to work. Will it be possible to secure the through conveyance of the incoming material by the flood? or must we expect the movement to be in wave masses, moved only at high stages? Experience abroad seems to indicate the latter. The problem will then be to reduce these masses to harmless proportions.

REMARKS ON GEORGE STEPHENSON.

By A. Mordecai, Member of the Civil Engineers' Club of Cleveland.

[Read July 12, 1881.]

The ninth of last month was the anniversary of an event that it seems to me should at least be noticed by a society of civil engineers, more especially of American engineers.

It was the 100th anniversary of the birth of George Stephenson, the father of the modern railroad, the man by whose energy and ability the practical success of the locomotive engine was first fully demonstrated.

George Stephenson then, as an old Bible has it, was born "June 9th day 1781," at Wylam, a small village about 8 miles from Newcastle, England.

His father Robert was an ordinary workman, the fireman of one of the pumping engines at a neighboring colliery, quite poor, but an honest, hard-working man, and he had that greatest of blessings, a most excellent mother, "a rale canny body," as her neighbors called her.

From the first, Stephenson understood that he must depend upon himself. The wages of a fireman in those days would not allow of any one remaining at home unemployed after he was able to earn a few pennies. So with no chance of obtaining an education, we find him at 8 employed at two pence a day looking after some neighbor's cows; the first work one would suppose a boy capable of doing; at 9 leading the horses at the plow, and then as he grew older and stronger rising by successive stages as picker, fireman, plugman and engineman, until at 18 he was earning $3 a week and had full charge of a pumping engine. Then it was that he first learned to read: and at 21, when he married, his signature in the parish register shows that even then he was by no means proficient with his pen.

At this time there seemed to have been nothing remarkable about the man, a good head with a high forehead and a very pleasing, kindly face set on a spare but vigorous frame, he was known about the village as an industrious, painstaking workman, who understood his work and could be relied upon. He, however, used his head at an early age, and took his pleasure first when a boy in making clay models of engines and then in taking real ones to pieces and examining all their parts, finding out the whys and wherefores, knowledge of which he afterwards made such good use.

In 1804, when 23, he moved to Killingworth, a village about 7 miles north of Newcastle, where he lived for about twenty years. Here he kept steadily at work ekeing out his wages by work of an evening in mending shoes, putting clocks to rights, or anything he could lay his hands on, not forgetting the improvement of his mind, in which he was helped by studying over lessons with his son Robert, who was then going to school.

It was about this time that the idea of applying steam as a motive power first dawned in the minds of a few men, who seeing the horses or mules straining every nerve to draw their load along the common road or the tramway, naturally asked themselves why the same power that did their pumping or sawing should not do their hauling; conse-

quently in 1802 Richard Trevethick, a Cornish miner, obtained a patent for a steam carriage and constructed one, which was the first application of steam-power to transportation on a common road, and in 1804 he constructed the first locomotive to work on a railroad.

Hearing of this, Mr. Blackett, a colliery owner at Wylam, ordered one to work his tramway, but for some cause it does not seem to have been a practical success; so Mr. Blackett, in connection with one Jonathan Foster, made one from ideas of his own, and tried it on the tramway in connection with his colliery.

This locomotive, however, on account of the poor construction of its details, and the poor quality of the permanent way it had to be run over, was constantly getting into trouble; it either broke down or got off the track, and horses had to be sent to take its place. With these failures to guide him and those of Blenkinsop and Chapman, both of whom built locomotives at about the same time, Stephenson set about making a new locomotive, and through the kindly aid of Lord Ravensworth, the owner of the colliery, who furnished the money, he on July 25, 1814, placed on the Killingworth Railway his first locomotive. From this time for some years he was constantly employed in experimenting on, and perfecting this machine, stopping aside for a moment to invent the Geordy safety lamp, which only shows more clearly the bent of this remarkable man's mind; wherever he saw a difficulty he was determined to surmount it.

In 1819 the owners of the Hetton Colliery, a few miles from Killingworth, determined to change their wagon road, used to haul the coal to the docks on the Wear into a railway, and appointed Stephenson their engineer. As the country was a rough one, he used inclined planes worked with stationary engines, and successfully opened the road on November 18, 1822.

Mr. Edward Peace, a gentleman living at Darlington, and having large interests in collieries near that place, conceived the idea of building a railway from thence to Stockton on the Tees, the point from which the coals were shipped to London. Being introduced to Stephenson, and seeing the performance of his Killingworth locomotives, he engaged him as the engineer of the line, and thus we find him at 42, in top boots and knee breeches running a level over the hills of Darham from morning to night, and putting the same energy and care in his work that he did in everything he undertook. The road was opened September 27, 1825, in the presence of an immense concourse of people, who had assembled to witness the first public opening of a railway operated by steam : little did they realize what a revolution it would produce.

In 1823, in company with Thomas Richardson, both putting in about $2,500, he bought a piece of land and established in New Castle the beginning of the locomotive works of George Stephenson & Co., now become so famous.

The Stockton & Darlington Railway was worked by stationary engines over the inclines, and on the levels, partly by horse, and partly by three locomotives ordered from George Stephenson & Co., at New Castle.

A few years before this, another project began to take definite shape namely, a railroad to connect the towns of Liverpool and Manchester.

As early as 1821, and indeed before, the inconvenience of the means of transportation between the two places had been seriously felt: vast piles of goods would remain for weeks, and even months, at one or other of the points, awaiting transit. It took as long to bring the raw cotton from Liverpool to Manchester as to bring it from New York to Liverpool. The Duke of Bridgewater's canal was not only taxed far beyond its capacity, but, being a monopoly, the rates charged were a very serious burden on the manufacturers of Manchester. It was in the midst of this state of things, and when the reaction from the tremendous strain of the Napoleonic wars had commenced in England, that, in 1821 Mr. James, a land agent in Staffordshire, and Mr. Sanders, a Liverpool merchant, formed the project of the Liverpool and Manchester Railroad, though their first idea was to operate it by horse-power. Surveys were commenced in that year; but such was the opposition of the land owners, the surveyors being often driven off literally by the point of the bayonet, and the serious difficulties that were encountered, that the project did not make much headway until 1824, when the first prospectus was issued, dated October 29. It is very different from the promising documents we see nowadays, and was most carefully and guardedly worded. The cost was set at $2,000,000, an amount, by the way, which was largely exceeded. The Stockton and Darlington road, as we have seen, being in progress, the projectors of the Liverpool and Manchester road sent a deputation to examine it, who were so much pleased with what they saw that Mr. Stephenson, then about 45, was appointed engineer of the new line.

He removed to Liverpool, and entered actively in his new duties, until September 15, 1830, when he saw all difficulties overcome and his labor crowned with success, and the Liverpool and Manchester Railroad, with steam for its motive power, formally opened to the public. From this time on until a few years before his death he was most actively engaged in the exercise of his profession.

From the Liverpool and Manchester he was appointed engineer of the London and Birmingham, with its celebrated Kilsby, where the difficulties he encountered must have seemed at that day insurmountable.

After the success of these two roads the mania for railroad building was at its height, and Stephenson was busy throughout England, and even in Belgium and Spain, giving his advice and assistance in pushing on in its course that remarkable system of railroads the world now uses.

When the Manchester and Liverpool Railroad was completed, he moved to Alton Grange, in Leicestershire, in which neighborhood he had extensive coal interests, and from thence to his country home at Tapton, in Derbyshire, where he passed the last years of his life among the delights of a country life, which he knew so well how to enjoy.

He died at Tapton on the 12th of August, 1848, in the sixty-seventh year of his life. His body is interred in Trinity Church, Chesterfield.

It may be truly said of such a man that he left behind him "foot-prints in the sands of time," that "a forlorn and shipwrecked brother, seeing, shall take heart again." There are few men, indeed, who have made

deeper or clearer impressions. Smiles' life is as interesting as a romance, and carries a much better moral. Not, that from a poor boy Stephenson lived to be a rich man, the companion of dukes and princes, but because he took every advantage possible of his opportunities, small though they were.

A poor boy, as we have seen, with his education obtained in that laborious manner, so admirably described by George Eliot (we may be sure that her "Bartle Massey" had no reason to complain of this scholar), not even endowed with what we would call a brilliant mind, by his indomitable energy, his perseverence, his thoroughness, his self-reliance and his strong common sense and good judgment, taking advantage of what others had done before him, he inaugurated, indeed, a new order of things, and left the world better than he had found it.

We who live in this age of railroads cannot appreciate the difficulties Stephenson had to encounter, not to speak of the general conservatism of human nature, nor the prejudices of the rich and powerful land-owners, nor the timidity of capitalists, nor the powerful opposition of canal and stage-coach interests. These were the real troubles in building the railroad over such a place as Chat Moss or under such a place as Kilsby Hill; and among these difficulties it is, that we can truly admire Stephenson's character. Nothing daunted, he surmounted difficulty after difficulty, and knew no such thing as permanent failure. Well it was for the railroad system that he was such a man. All his undertakings he successfully accomplished; no one afterwards completed what he had failed to do; and in the questions that agitated the public mind in his time—such as the width of gauge, the advantage of grades, etc.—we find him on the side that experience has shown to be the right one.

Before the Parliamentary committee, Stephenson showed a confidence in his own ideas that was remarkable and was not shaken by a most exhaustive cross-examination carried on by eminent counsel, who knew so well how to turn and twist him. One of his replies is worth mentioning: The counsel having exhausted all the imaginary troubles incident to a locomotive going at the then unheard of speed of 10 miles an hour, asked: "But suppose a cow gets on the track, would it not be a very awkward circumstance?" Stephenson replied: "Yes; very awkward, indeed—for the cow."

Though Stephenson was always modest, easily approached, and was never arrogant or offensive in his manner, the day must have been a proud one when on October 1, 1829, he saw the immense crowd witness his success at Rainhill with the Rocket, or on that other day when all the principal dignitaries of the land, with thousands of others, came to do him honor on the opening of the Liverpool & Manchester Railroad. It was my pleasure last evening to hear an account of this opening from a very intelligent lady living in Cleveland, who was an eye witness of the event.

She well remembers when a girl of 7 being lifted upon her father's shoulders to see the little Rocket shoot into Manchester, first for the physicians for poor Mr. Huskinson, and then, bringing the train load of distinguished people. The railroad at the bottom of a deep cutting whose sides were lined with crowds of people, the bustle and excitement

were vividly impressed upon her memory, and she gave me a most interesting account of it.

Indeed, the Duke of Wellington on that day witnessed a victory over time and space, just as well fought for and as hard to earn, but much more far-reaching in its consequences, and fraught with much more comfort and happiness to mankind, than any battle he or any other general has ever won.

Dazzled with "the pomp and circumstance of war," the world has been profuse in raising statues to its Wellingtons and Napoleons, the monuments to Stephenson and the illustrious men who have followed him on both sides of the Atlantic have, with but few exceptions, been erected by themselves in the works they have constructed.

I wish I had the time for giving, and you the patience for hearing this warm evening a history of the modern railroad, starting early in the nineteenth century, with its wooden rails, first laid down near Newcastle, then seeing them strapped with iron, then iron rail laid in 1838; first cast, then wrought; with its chair and fish plate, not forgetting the outram for short tramroads with their stone blocks, reaching at last the modern railroad with its stone ballast, wood or iron ties, steel rail, its switches, frogs and crossings, electric signals, and everything in fact that makes the nearly perfect permanent way we see to-day: or the history of the locomotive engine, commencing again in the mining districts with some happy thought of Watt, and so up through the difficulties found in making steam fast enough, in connecting the parts, in giving elasticity to the engine through the different improvements of Cugnot, of our own Evans, of Trevethick, of Blenkinsop, of Chapman, of Stephenson, until we reach the modern consolidated locomotive, the triumph of engineering skill.

I will only suggest to some members of the club better able to handle them than I am, these topics for two very interesting and instructive papers.

In considering both of them we find Stephenson's brains and energy doing wonderful work; the patent chair and rail, the throwing of the exhaust into the smoke-stack of an engine—a happy inspiration like that of Howe in putting the eye in the point of the needle—the multitubular boiler, the springs, aye, even the automatic safety brake, all show his genius.

It is needless for me to make any remarks upon the benefit of the system that Stephenson inaugurated, or show what a revolution it has produced.

In the current number of the *International Review*, Mr. Edward Atkinson shows that the value in New York of 20 bbls. of flour, 10 bbls. of beef and pork, 100 bus. each of wheat, corn and oats, and 100 lbs. each of butter, lard and wool, had raised but very little in 10 years, being worth in 1869 $\$632\frac{68}{100}$, and in 1880 $\$631\frac{32}{100}$, but the cost of transporting these products from Chicago to New York has decreased so much that the saving to the farmer since the war has been 1,200 million dollars, 100 million dollars more than the reduction of the national debt during the same period; hence, he argues that not a single man in this broad land has worked one hour longer or harder in paying this immense sum. Again he shows

that although we are building railroads at a fearful rate this year. probably costing 300 millions of dollars, that sum was actually saved by the reduction in the freights on the goods transported in the one year of 1879.

If these millions were saved in one year by merely the improvements made in railroads, no language that I can command will give you the slightest conception of the millions and millions of millions that have been saved by their introduction.

The growth of this system is extraordinary; starting with the Stockton and Darlington, a little road 8 miles long opened only 50 years ago, it now goes everywhere and is thousands of miles in length. Knotted together we might represent a modern Atlas binding the world to his shoulder by bands of iron passing many times around it, and all accomplished in the length of a single lifetime.

What it is destined to do in the future no one can tell; the civil engineer can indulge in no Alexandrian sigh; there are other worlds to conquer, and it is England and the English-speaking nations who, in South America, in Africa, in Asia, everywhere are pushing forward the arts of civilization. It is America and American engineers that the world will look to for the solution of problems similar to those they have worked out so successfully in this country. Two hundred years ago this was a wilderness. Is it too bold to imagine that we can see in our mind's eye, 200 years hence, some harbor on the now barbarous coast of Africa, let us say, being improved by a Wilson with works that excite the admiration of the world, or a railroad system covering the continent, built by a Latimer and managed by a Paine (whatever the motive power), with such consummate ability that the safest place to be is on a railroad train running at full speed; the rivers spanned with cobweb-like structures of steel or iridium erected by some Sheldon or Porter, and plying on their surface, moving steadily and swiftly, vessels propelled by machinery constructed by some Holloway, cities dotting their banks full of magnificent buildings designed by a Richardson or a Coburn, with a Morse taking watchful care of their interests; a healthy sewerage system constructed by a Rawson, supplied with water by a Kingsley, with gas by a Hyde, their allotments plotted carefully by a Burgess—aye even their suburban park laid out by a Schwagerl with such art that we scarcely recognize nature, so much has it been improved upon?

Who can doubt that the descendants of these men and such as they, when the time comes, will surmount the difficulties they will have to encounter with the same zeal, energy and ability they themselves have shown in this country, with the same success? But let us sincerely trust with a much greater amount of worldly profit for themselves.

CRYSTALLIZATION AND ITS EFFECTS UPON IRON.

BY N. B. WOOD, MEMBER OF THE CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read January 10, 1882.]

The question has been asked* "what is the chemically scientific definition of crystallization?" Now as the study of crystallization and its effect upon matter physically as well as chemically will be of interest, considering the subject matter for discussion, I shall not only endeavor to answer the question, as I understand it, but try to treat it somewhat technologically.

Having this object in view, I have prepared or brought about the conditions necessary to the formation of a few crystals of various chemical substances, which for various reasons, such as lack of time and bad weather, are not as perfect as could be desired, but will perhaps subserve the purpose for which they were designed. I think you will agree with me that they are beautiful, if they are imperfect, and I can assure you that the pleasure of watching their formation fully repays one for the trouble, if for no other reason than the mere gratification of the senses. From the earliest times and by all races of men, the crystal has been admired and imitated, or improved by cutting and polishing into faces various substances. I have also procured specimens of steel and iron which show the effect of crystallization, which was produced (perhaps) under known conditions, so that the conclusions which we arrive at from their study will have a fair chance of being logical, at least, and perhaps of some practical value.

When we examine inanimate nature we find two grand divisions of matter, *fluid* and *solid*. These two divisions may be subdivided into, the former gaseous and liquid ; the latter, amorphous and crystalline, but whether one or the other of these divisions be considered, their ultimate and common division will be the ATOM. By the atom we understand that portion of matter which admits of no further division, which, though as inconceivable for minuteness as space is for extent, has still definite weight, form and volume ; which under favorable circumstances, has that power or force called cohesion, the intensity of which constitutes strength of material, which every engineer is supposed to understand, but which lies far beyond the powers of the human mind for comprehension or analysis. When we apply a magnet to a mass of iron filings we observe the particles arrange themselves in regular order, having considerable strength in one direction and very little or none in any other. Now although we understand very little about the force which holds these particles in position, we do know that it is actual force applied from without and maintained at the expense of some of the known sources of force. But the force or power or property of cohesion seems to be a quality stored within the atom itself, in many cases similar to magnetism, having powerful attraction in some directions and very little or none in others. A crystal of mica, for instance, or gypsum may be di-

* By Rev. J. W. Browne, member of the club.

vided to any degree of thinness, but is very difficult to even break. This property of crystals is termed cleavage. Cohesion and crystallization are affected variously by various circumstances, such as heat or its absence, motion or its absence, etc. In fact almost every phenomenon of nature within the range of ordinary temperatures has effects which may be favorable to the crystallization of some substances, and at the same time unfavorable to others; so it will be seen that it is impossible to lay down any rule for it except for named substances, like substances requiring like conditions, to bring its atoms into that state of equilibrium where crystallization can occur. If we examine crystals carefully we find, not only that nature has here provided geometric forms of marvelous beauty and exactness, with faces of polish and quoins of acuteness equal to the work of the most skillful lapadist, "but that in whatever manner or under whatever circumstancos a crystal may have been formed, whether in the laboratory of the chemist or the workshop of nature, in the bodies of animals or the tissues of plants, up in the sky or in the depths of the earth, whether so rapidly that we may literally see its growth, or by the slow aggregation of its molecules during perhaps thousands of years, we always find that the arrangement of the faces are subject to fixed and definite laws." We find also that a crystal is always finished and has its form as perfectly developed when it is the minutest point discernable by the microscope as when it has attained its ultimate growth. I might add parenthetically that crystals are sometimes of immense size, one at Milan of quartz being 3 feet 3 inches long and 5 feet 6 inches in circumference, and is estimated to weigh over 800 pounds; and a gigantic beryl at Grafton, N. H., is over 4 feet in length and 32 inches in diameter, and weighs not less than 5,000 pounds: but the most perfect specimens are of small size, as some accident is sure to overtake the larger ones before they acquire their growth, to interfere with their symmetry or transparency. This you will see abundantly illustrated by the examples which I have prepared, as also the constancy of the angles of like faces. Chemically speaking, the crystal is always a perfect chemical body, and can never be a mechanical mixture. This fact has been of great value to the science of chemistry in developing the atomic theory, which has demonstrated that a body can only exist chemically combined when a definite number of atoms of each element is present, and that there is no certainty of such proportions existing except in the crystal. I hold before you a crystal of common alum. Its chemical symbol would be $Al_2O_3\ 3SO_3 + KO.SO_3 + 24H_2O$. If we knew its weight and wished to know its ultimate component parts, we could calculate them more readily than we could acquire that knowledge by any other means. But the elements of this quantity of uncrystallized alum could not be computed. Then we may define crystallization to be the operation of nature wherein the chemical atoms or molecules of a substance have sufficient polarized force to arrange themselves about a central attracting point in definite geometrical forms.

Fresenius defines it thus: "*Every operation, or process, whereby bodies are made to pass from the fluid to the solid state, and to assume* certain fixed, *mathematically definable, regular forms.*" It would be folly for me to attempt to criticise Fresenius, but I give you both definitions, and you

can take your choice. The definition of Fresenius, however, will not suit our present purpose, because the crystallization of wrought iron occurs, or seems to, *after* the iron has acquired a *solid state*.

Iron, as you all know, is known to the arts in three forms: Cast or crude, steel, and wrought or malleable. Cast iron varies much in chemical composition, being a mixture of iron and carbon chiefly, as constant factors, with which silicium in small quantities (from 1 to 5 per cent., phosphorus, sulphur and sometimes manganese (*e. g.* spiegeleisen) and various other elements are combined. All of these have some effect upon the crystalline structure of the mass, but whatever crystallization takes place occurs at the moment of solidification, or between that and a red heat, and varies much according to the time occupied in cooling as to its composition. My own experience leads me to think that a cast iron having about three per cent. of carbon, a small percentage of phosphorus, say about ½ of one per cent., and very small quantities of silicum, the less the better, and traces of manganese (the two latter substances *slagging* out almost entirely during the process of remelting for casting) makes a metal best adapted to the general use of the founder. Such proportions will make a soft, even-grained, dark gray iron, whose crystals are small and bright, and whose fracture will be uneven and sharp to the touch. The phosphorus in this instance gives the metal liquidity at a low temperature, but does not seem to influence the crystallization to any appreciable extent. The two elements to be avoided by the founder are silicium and sulphur. These give to iron a peculiar crystalline appearance easily recognizable by an experienced person. Silicium seems to obliterate the sparkling brilliancy of the crystalline faces of good iron, and replace them with very fine dull ones only discernible with a lens, and the iron breaks more like stoneware than metal, while sulphur in appreciable quantities gives a striated crystalline texture similar to chilled iron and very brittle. Phosphorus in very large quantities acts similarly. The form of the crystal in cast-iron is the octahedron, so that right angles with sharp corners should be avoided as much as possible in castings, as the most likely position for a crystal to take would be with its faces along the line of the angle. Steel, to be of any value as such, *must* be made of the purest material. Phosphorus and sulphur *must* not exist, except in the most minute quantities, or the metal is worthless. If either of these substances be present in a bar of steel, its structure will be coarse, crystalline and weak. The reason of this is unknown, but probably their presence reduces the power of cohesion; and, that being reduced, gives the molecules of steel greater freedom to arrange themselves in conformity with their polarity, and this in its turn again weakens the mass by the tendency of the crystals to cleavage in certain directions. Carbon is a constant element in steel, as it is in cast iron, but is frequently replaced by chromium, titanium, etc., or is said to be, though it is not quite clear to me how it can be so if steel is a chemical compound. However this may be, we know that a piece of good soft steel breaks with a fine crystalline fracture, and the same piece hardened when broken shows either an amorphous structure or one very finely crystalline, which would indicate that the crystals had been broken up by the action of heat and that they had not had sufficient time to re-

turn to their original position on account of the sudden cooling. The tendency of the molecules of steel after hardening to assume their natural position when cold seems to be very great, for we have often seen large pieces of steel burst asunder after hardening, though lying untouched, and sometimes with such force as to hurl the fragments to some distance. If a piece of steel be subjected to a bright yellow or white heat, its nature is entirely changed and the workman says it is burnt. Though this is not actually a fact, it does well enough to express that condition of the metal. Steel cannot be burnt unless some portion of it has been oxidized. The carbon would of course be attacked first, its affinity for oxygen being greatest: but we find nothing wanting in a piece of burnt steel. It can, by careful heating, hammering and hardening, be returned to its former excellence. Then what change has taken place? I should say that two modifications have been made, one physical, the other chemical. The change chemically is that of a chemical compound to a mixture of carbon and iron, so that in a chemical sense it resembles cast iron. The change physically is that of crystallization, being due partly to chemical change and partly to the effect of heat. I have procured a specimen of steel showing beautifully the effect of overheating. The specimen is labeled No. 1, and is a piece of Park Brothers steel (one of the best brands made in America). It has been heated at one end to proper heat for hardening and at the other is what is technically called "burnt." It has been broken at intervals of about 1½ inches, showing the transition from amorphous or proper hardening to highly crystalline or burnt. Malleable or wrought-iron is or should be pure iron. Of course in practice it is seldom such, but generally nearly so, being usually 98, 99, or even more per cent. It is exceedingly prone to crystallization, the purer varieties being as much subject to it as others, except those contaminated with phosphorus, which affects it similarly with steel, and makes it very weak to cross and tensile strains. I have never estimated the quantity present in any except one specimen, a bar of 1½ round, which literally fell to pieces when dropped across a block of iron. It had 1.32 per cent. of phosphorus and was very crystalline, though the crystals were not very large. Iron which has been, when first made, quite fibrous, when subjected to a series of shocks for a greater or less period, according to their intensity, when subjected to intense currents of electricity, or when subjected to high temperatures, or has by mechanical force been pushed together, or, as it is called, upset, becomes extremely crystalline. Under all of these circumstances it is subjected to one physical phenomenon, that of motion. It would seem that if a bar of iron were struck, the blow would shake the whole mass, and consequently the relative position of the particles remain unchanged, but this is not the case. When the blow is struck it takes an appreciable length of time for the effect to be communicated to the other end so as to be heard if the distance is great. This shows that a small force is communicated from particle to particle independently along the whole mass, and that each atom actually moves independently of its neighbor. Then, if there be any attraction at the time tending to arrange it differently, it will conform to it. So much for theory with regard to this important matter. It looks well on paper, but do the facts of the case cor-

respond? If practically demonstrated and systematically executed experiments fail to corroborate the theory, and if, furthermore, we find there is no necessity for the theory, we naturally conclude that it is all wrong, or, at least, imperfectly understood. Now there is one other quality imparted to iron by successive shocks, which, I think, is independent of crystallization, and this quality is hardness and consequent brittleness. One noticeable feature about this also is, that as "absolute cohesion" or tensile strength diminishes, "relative cohesion" or strength to resist crushing increases. Specimens Nos. 2, 3, and 4 are pieces of Swedish iron probably from the celebrated mines of Dannemora. Nos. 2 and 3 are parts of the same bolt, which, after some months use on a "heading machine" in a bolt and nut works, where it was subjected to numerous and violent shocks (perhaps 50,000 or 60,000 per day), it broke short off, as you see in No. 2, showing a highly crystalline fracture. To test whether this structure continued through the bolt I had it nicked by a blacksmith's cold chisel and broken. The specimen shows that it is still stronger at that point than at the point where it is actually broken, but the resulting fracture shows the same crystalline appearance. I next had specimen No. 4 cut from a fresh bar of iron which had never been used for anything. It also shows a crystalline fracture indicating that this peculiarity had existed in the iron of both from the beginning.

I next took specimen No. 3 and subjected it to a careful annealing, taking perhaps two hours in the operation. Although it is a 1⅛ bolt and has V threads cut upon it we are unable to break it, although bent cold through an arc of 90° and probably would have doubled upon itself if we had had the means to have forced it. Now what does this show? Have the crystals been obliterated by the process of annealing, or has only their cleavage been destroyed, so that when they break instead of showing brilliant, sparkling faces they are drawn into a fibrous looking mass? The latter seems to be the most plausible theory, to which I admit objections may be raised. For my own part, I am inclined to the belief that the crystal exists in all iron which is finished above a bright red heat, and that between that and a black heat they are formed and have whatever characteristics circumstances may confer upon them, modified by the action of agencies heretofore mentioned.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

WESTERN SOCIETY OF ENGINEERS.

May 16, 1882:—The 147th regular meeting was held at 4 P. M., Vice-President Booth in the chair.

The minutes of the preceding meeting were read and approved.

Mr. Lyman Bridges, Chief Engineer California Central Railway and Ocean Shore Railroad, of San Francisco, Cal., was elected a member.

The Committee on Seal presented the following report:

Chicago, May 15, 1882.

To the Western Society of Engineers:

The Committee on Seal beg leave to submit the accompanying design, prepared by Mr. G. A. M. Liljencrantz, for the corporate seal of this Society, and to report that they consider it the most appropriate design which they have examined, and that they hereby recommend its adoption by the Society as the corporate seal.

Respectfully submitted.

Wm. S. MacHarg, Chairman.

On motion of Col. FitzSimons the report of the Committee was accepted and its recommendation adopted.

A vote of thanks was passed to the different members who had presented designs for a seal, and Mr. Liljencrantz was requested to prepare a written description of the seal adopted.

The following resolution, prepared by Mr. Artingstall, was adopted:

Resolved, That the Committee on Seal be authorized to procure a proper seal in accordance with the design adopted, for use of the Society.

Mr. Liljencrantz submitted the following resolution, which was adopted:

Resolved, That the Secretary be requested to prepare and submit to the Society a list of all standing and special committees now in existence, and be it further

Resolved, That suitable blanks be prepared and printed, to officially notify members appointed to serve on committees of their appointment; such blanks to be filled and mailed by the Secretary to each member of a committee, as soon as practicable after appointment.

Mr. Miller gave a description of some details in the working of the cable street railroad recently put in operation on State street. The following resolution, presented by Col. FitzSimons, was adopted:

Resolved, That our member of the Board of Managers of the Association of Engineering Societies be requested to arrange matters so that parties reading and submitting papers may have an opportunity of reading proof-sheets and correcting the same before publication, if they desire to do so.

[*Adjourned.*] L. P. Morehouse, Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. I. JUNE, 1882. No. 8.

This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

TO THE ENGINEERS OF AMERICA.

Gentlemen :

The Board of Managers of the Association of Engineering Societies respectfully call your attention to the following:

The four societies of engineers at Chicago, Boston, Cleveland and St. Louis entered into an arrangement for publishing their papers and transactions in common, and this has been done since last November. We can say with satisfaction, that, with the exception of some delay due to the novelty of the experiment and the inexperience of the management, which is not likely to again occur, the result has been eminently successful.

By this arrangement we have secured valuable results at a moderate cost; but we would ask you, shall this end here?

Why should not the societies at Pittsburgh, Philadelphia and Denver, and the broader associations, namely, the American societies of Civil Engineers and of Mechanical Engineers, and the Institute of Mining Engineers and the Master Mechanics' Association, also publish with us? They could also issue separately if desired, exactly as one gets a hundred copies of his paper issued in pamphlet form in any one of these bodies. Although perhaps no man would care for the whole of any one number issued, yet the result would be a journal without equal in the world, and the engineering profession generally would be largely benefited thereby.

We ask you individually to think of this matter, and if it meets your approbation, see if you cannot help to bring about so desirable a result. There are of course difficulties, but experience has shown that there are none which are insuperable. While what we deem a good beginning has been made, and great advantages have been derived, and we believe will continue to be derived form the present arrangement, we fully realize that much more can be accomplished than is now possible, but that it

cannot be done without your aid to secure the co-operation of the engineering societies of the land.

We feel confident that if the matter is intelligently discussed in the society to which you belong, something will be accomplished. We therefore earnestly commend the undertaking in which our four societies have engaged to your friendly consideration.

(Signed.)

BENEZETTE WILLIAMS,
for Western Society of Engineers.

S. E. TINKHAM,
for Boston Society of Civil Engineers.

PROF. CHAS. A. SMITH,
for Engineers' Club of St. Louis.

M. E. RAWSON,
for Civil Engineers' Club of Cleveland.

JUNE, 1882.

NOTES ON CO-ORDINATE SURVEYING.

BY WM. E. MCCLINTOCK, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read June 21, 1882.]

The object of any land survey is to locate a particular parcel of land in such a manner as to enable a competent person to identify the same at any future time, or to so locate different topographical features and bounds, with reference to each other, as to make a map or plan.

The old compass, as used by our grandfathers, was so eccentric in its movements and so easily affected by local causes, that but very indifferent results could possibly be obtained with it. With the increased value of land, greater accuracy is required and different methods are of necessity employed, not only in the survey itself, but in defining the bounds. I do not propose to discuss the different methods in this paper, but simply to describe a method that may be used to advantage, and, as I think, absolutely relied on for any future time. If there are weak points or prolix arguments, I trust discussion may help to eliminate them and a more simple and effective system be the result.

For a careful survey either to describe a parcel of land or to plot the same, the rectangular, co-ordinate system seems to be the most permanent in the results obtained, inasmuch as it locates a point with reference to a series of points, scattered over an indefinite area in such a manner as to enable a competent person to relocate any one point if but two other points in any part of the system can be found.

The reference of all points to the international origin of co-ordinates, Greenwich, seems to be the one that is best adapted when practicable although it may be advisable to take some one well marked and prominent point of this kind for an origin, and the azimuth from this to a second as the base, and then refer all other points in the survey to this origin, either by means of a carefully checked traverse line or triangles; depending on local circumstances as to which method shall be employed.

In any part of Massachusetts it is possible to find one or more triangulation points, as the whole State was covered by a thorough system of

triangles many years ago. Any data connected with this scheme of triangulation could probably be obtained by writing to Prof. J. E. Hilgard Superintendent of U. S. Coast and Geodetic Survey, as descriptions of points, as well as positions, are on file at the Washington office.

Judgment must be used in this, as well as any other method of surveying, to lay out the work according to the requirements in the case. What would be a good survey among the Berkshire Hills would hardly pass where land is valued by the foot, and what would be a good survey in Boston would hardly be warranted on Cape Cod sands, where land hasa small value.

The first point I propose to dwell upon is to survey a section, either small or large, in order to construct a complete map of the same, and to locate bounds where land has the value of ordinary farming land.

First, a general knowledge of the territory is needed with reference to locating points in such positions as to make well conditioned triangles—that is, with no angle less than about thirty degrees; and points want to also be intervisible.

Such positions are selected as have commanding views, and to cover the desired area with the use of as few in number as possible.

Next we place intermediate points between the first to cover the territory more thoroughly. These positions should be carefully marked by means of a granite post, good oak or a cedar hub, or drill hole in ledge or large boulder, and a careful sketch made which shall show the relative positions of local objects with measures to distinguishing objects and ranges to distant objects when practicable.

After selecting and marking the point a signal can be erected on which to observe from other points. A 2-inch square piece with corners chamfered off to make eight sides gives a good signal on which to observe, and if it be painted in black and white stripes and has a black or white flag, or both if needed, to distinguish when several points range near each other, there will be no difficulty in observing on the correct point. Drive a nail into end of pole leaving about one inch projecting; place this projecting nail in the drill hole in ledge or corresponding boring in hub in order to prevent base of pole from being knocked out of position; use three 3″ × 1 braces pointed at one end, to be so placed as to divide the circle equally; drive into ground until firm and nail to pole when the same is plumb.

The braces should be nailed opposite each other on the poles with no two on same side. Having the signals all ready, a scheme of triangles and needed angles should be made out so as to prevent the possibility of having to go the second time to a station, to observe angles forgotten for want of system.

The accuracy of the work will depend on well centered and plumb signals and carefully bisecting same at each observation; in having the instrument exactly over the point at all times; in having all the adjustments always made; in having a good instrument, and above all in carefully repeated observations.

The number of repetitions of any angle must depend on the importance of the triangle, giving most weight to a triangle when it is one of a scheme to cover a large area, twelve, twenty-four, thirty-six, or even more observations being taken in order to reduce the instrumental error to its minimum.

It will be found convenient to take a multiple of six, as the angle can be more readily carried out by so doing, the remainder left after dividing any denomination by six, forming the left-hand figure in next lower denomination.

After setting up instrument at zero, set on the left hand of two points; clamp the limb and unclamp vernier plate; direct telescope to right hand of two points, and, after carefully bisecting, clamp vernier plate; unclamp limb, and set the reading of vernier under the zero reading for the approximate angle sought. Then repeat this process six times, and set the reading under first: this reading, divided by six, will give the angle. Reverse the telescope and set on first signal, and so repeat the process six times more, and place the reading beneath the last reading: the preceding reading, subtracted from last one and the remainder divided by six, will give a second angle, and the mean of last two sets will give one completed angle.

By repeating the above process as many times as required, the angle can be had with any desired degree of accuracy, for example:

INSTRUMENT AT A.

		360° 00′ 00″			
B	1	97° 02′ 10″			
C	6	222° 9′ 50″	97° 1′ 38.3″		
	6	84° 20′ 10″	43.3″	97° 1′ 40.8″	
	6	306° 30′ 30″	97° 1′ 43.3″		
	6	168° 41′ 11″	46.7″	97° 1′ 45.0″	97° 1′ 42.9″

Having all the angles observed, the three angles in any triangle should be summed up, and if they materially differ from 180 the observations should be repeated until the difference falls within an accepted standard, say 6″ for the large triangles, and 20″ for smaller ones, the error, whatever it is, to be equally distributed over the three angles.

Having checked all the notes, and re-observed where necessary, we are ready to compute the positions—

1st. Having latitude, longitude, length of base and azimuth.

2d. Having latitude and longitude only to start with.

For all practical purposes in any ordinary town, this triangle can be treated as plane, as the correction for spherical shape of earth is too small to affect results.

When the sides exceed ten or twelve miles the correction can be applied.

For convenience of work and filing, it will be found advantageous to tabulate the formula; and for triangular sides use paper 10 × 8 inches, fine ruled, and put four triangles on each page; draw the lines and print on the headings with the proper ink and sixty or more pages can be printed by the "Hektograph"; for example:

No.	Denomination.		Observed Angles.				Logarithm.
	A to B					893.21	2.950 9540
1	C	18	53°24′25.4″	-0.5″		53°24′24.9″	0.095 3442
	A	18	50 05 23.3	-0.5		50 05 22.8	9.884 8233
	B	18	76 30 12.9	-0.6		76 30 12.3	9.987 8378
			1.6			00.0	
	C to B					853.34	2.931 1215
	C to A					1081.77	3.034 1360

The first column is number of triangle; second, triangle observed; third, repetitions for each angle; fourth, observed angle ; fifth, correction necessary to make three angles equal 180° ; sixth and seventh, for spherical excess ; eighth, corrected angles and distances : ninth, logarithms of eighth. Having all the sides of the different triangles, we next proceed to find the difference in latitude and longitude and azimuth for new points: for this use the formula in all work where sides do not exceed twelve miles :

$$-dL = KB\ cos.\ Z + K^2\ C\ sin.^2\ Z + h^2\ D \quad (1)$$

$$dM = \frac{A'\ K\ sin.\ Z}{} \quad (2)$$

... the nearest second.

Radius of curvative of meridian $= R = \frac{N^3}{a^2}\ (1 = \varepsilon^2) = \frac{a\ (1-\varepsilon^2)}{(1-\varepsilon^2\ sin.^2\ L)^{\frac{3}{2}}}$

$$N = \frac{a}{\left[1-\varepsilon^2 sin.^2\ \tfrac{1}{2}(L+L')\right]^{\frac{1}{2}}} = \text{normal at middle latitude.}$$

Eccentricity of earth $= \varepsilon = \left(\frac{a^2-b^2}{a^2}\right)^{\frac{1}{2}} = \left(\frac{(1-b^2)}{a^2}\right)^{\frac{1}{2}} = 2\varepsilon - \varepsilon^2.$

Ellipticity $= E\ \frac{a-b}{a} = 1 - \frac{b}{a}$, or very nearly $\varepsilon^2 = 2E.$

Equatorial radius a = 6,377,397.16 metres.

Polar radius b = 6,356,078.96 metres.

The algebraic sign of dL or dM will depend on what quadrant the Z is in ; viz. :

	180°	
	Sin. Z + / *Cos. Z* —	*Sin. Z* — / *Cos. Z* —
90°		270°
	Sin. Z + / *Cos. Z* +	*Sin. Z* — / *Cos. Z* +

I would recommend to any who may wish to use the above formulæ that the easiest way to obtain values for A, B and C would be to send to the U. S. Coast and Geodetic Survey Office and get Appendix No. 36, "Formulæ, tables and example for the geodetic computation of latitudes, longitudes and azimuth of trigonometrical points, etc."

When only the latitude and longitude of two points are given.

In equation (1) we have with small corrections : $-dL = KB\ cos.\ Z$.

In the same way from equation (2) $dM = \frac{A'\ K\ sin.\ Z}{cos.\ L}$. The unknown

It will be found convenient to take a multiple of six, as the angle can be more readily carried out by so doing, the remainder left after dividing any denomination by six, forming the left-hand figure in next lower denomination.

After setting up instrument at zero, set on the left hand of two points: clamp the limb and unclamp vernier plate; direct telescope to right hand of two points, and, after carefully bisecting, clamp vernier plate; unclamp limb, and set the reading of vernier under the zero reading for ... Then repeat this process six times, and ...

ERRATA.

In equation (2) the denominator of the second term should be $\cos. L$. Insert after equation (3), when log. of h is less than 2.31 the third term in equation (1) may be omitted.

In formula for value of ε for $\left(\frac{(1-b^2)}{a^2}\right)^{\frac{1}{2}} = 2\,\varepsilon - \varepsilon^2$ read $\left(1-\frac{b^2}{a^2}\right)^{\frac{1}{2}} = 2\,E - E^2$. In formula for ellipticity read Ellipticity $= E = \frac{a-b}{a}$.

Having ... be summed up, and if they materially differ ... should be repeated until the difference falls within an accepted standard, say 6″ for the large triangles, and 20″ for smaller ones, the error, whatever it is, to be equally distributed over the three angles.

Having checked all the notes, and re-observed where necessary, we are ready to compute the positions—

1st. Having latitude, longitude, length of base and azimuth.

2d. Having latitude and longitude only to start with.

For all practical purposes in any ordinary town, this triangle can be treated as plane, as the correction for spherical shape of earth is too small to affect results.

When the sides exceed ten or twelve miles the correction can be applied.

For convenience of work and filing, it will be found advantageous to tabulate the formula; and for triangular sides use paper 10 × 8 inches, fine ruled, and put four triangles on each page; draw the lines and print on the headings with the proper ink and sixty or more pages can be printed by the "Hektograph"; for example:

No.	Denomination.		Observed Angles.				Logarithm.
	A to B					893.21	2.950 9540
1	C	18	53°24′25.4″	−0.5″		53°24′24.9″	0.095 3442
	A	18	50 05 23.3	−0.5		50 05 22.8	9.884 8233
	B	18	76 30 12.9	−0.6		76 30 12.3	9.987 8378
			1.6			00.0	
	C to B					853.34	2.931 1215
	C to A					1081.77	3.034 1360

The first column is number of triangle; second, triangle observed; third, repetitions for each angle; fourth, observed angle; fifth, correction necessary to make three angles equal 180°; sixth and seventh, for spherical excess; eighth, corrected angles and distances; ninth, logarithms of eighth. Having all the sides of the different triangles, we next proceed to find the difference in latitude and longitude and azimuth for new points; for this use the formula in all work where sides do not exceed twelve miles:

$$-dL = KB\ cos.\ Z + K^2\ C\ sin.^2\ Z + h^2\ D \quad (1)$$

$$dM = \frac{A'\ K\ sin.\ Z}{cos.\ L.} \quad (2)$$

$$-dZ = dM\ sin.\ \lambda \quad (3)$$

dL = difference in lat.; dM = difference in long.; dZ = difference in azimuth; K = given geodetic distance between two points; L = given lat. of first point; M = long. of the same; Z = the given azimuth of the first to the second point, counting from south round by west, and let dL, dM, dZ = the difference in lat., long. and azimuth of the second points expressed in seconds of arc.

In equation (1) $B = \frac{1}{R\ arc\ 1''}$; $C' = \frac{tan.\ L}{2\ N\ R\ arc\ 1''}$

$$D = \frac{\frac{3}{2}\ \varepsilon^2\ sin.\ L\ cos.\ L\ arc\ 1''}{(1-\varepsilon^2\ sin^2\ L)^{\frac{3}{2}}}$$

$$h = K\ B\ cos.\ Z$$

$A = \frac{1}{N\ arc\ 1''}$ referring to the second point as indicated by the accented A'; $\lambda = \frac{1}{2}(L + L')$.

$-dL$ and dM should be computed to thousandths of seconds; $-dZ$ to tenths, and for less important points the nearest second.

Radius of curvative of meridian $= R = \frac{N^3}{a^2}(1 = \varepsilon^2) = \frac{a\ (1-\varepsilon^2)}{(1-\varepsilon^2\ sin.^2\ L)^{\frac{3}{2}}}$

$$N = \frac{a}{\left[1-\varepsilon^2 sin.^2\ \frac{1}{2}(L+L')\right]^{\frac{1}{2}}} = \text{normal at middle latitude.}$$

Eccentricity of earth $= \varepsilon = \left(\frac{a^2-b^2}{a^2}\right)^{\frac{1}{2}} = \left(\frac{(1-b^2)}{a^2}\right)^{\frac{1}{2}} = 2\varepsilon - \varepsilon^2.$

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The algebraic sign of dL or dM will depend on what quadrant the Z is in: viz.:

	180°	
	Sin. Z + | *Sin. Z* —	
	Cos. Z — | *Cos. Z* —	
90°		270°
	Sin. Z + | *Sin. Z* —	
	Cos. Z + | *Cos. Z* +	

I would recommend to any who may wish to use the above formulæ that the easiest way to obtain values for A, B and C' would be to send to the U. S. Coast and Geodetic Survey Office and get Appendix No. 36, "Formulæ, tables and example for the geodetic computation of latitudes, longitudes and azimuth of trigonometrical points, etc."

When only the latitude and longitude of two points are given.

In equation (1) we have with small corrections: $-dL = KB\ cos.\ Z$.

In the same way from equation (2) $dM = \frac{A'\ K\ sin.\ Z}{cos.\ L}$. The unknown

terms are K and Z, and in the first equation we have the product of K and *cos.* Z: in the second equation the product of K and *sin.* Z: by dividing K *sin.* Z: by K *cos.* Z we have *tan.* Z. Having the product of K and Z, by finding a value to Z, it is easy to find K by a simple division. Having K and Z the problem is the same as before mentioned.

The permanent points, such as church spires, cupolas, flag poles and house gables will be determined by observing from one or two bases and concluding the angle at inaccessible apex. Having a sufficient number of points determined to cover the territory to be surveyed our next step will be to make a sheet of convenient size (antiquarian is very convenient) and plot the points determined, with reference to the parallels and meridian. The convergence of meridians will be inappreciable and the length of middle squares can be used on the area covered by any ordinary sized city when the scale is large: but if the scale is small, say $\frac{1}{10000}$ or smaller, then this correction will have to be consider and each square will have a different value.

Lay out the parallel of latitude running as near through the centre of the sheet as possible, erect a right angle to this for the centre meridian. Lay off on the parallel the divisions it is proposed to use, say five seconds for $\frac{1}{1200}$ scale, ten seconds for $\frac{1}{2400}$ scale and one minute for $\frac{1}{10000}$ scale.

Lay off the same number of seconds of latitude on the meridians and draw lines through these points parallel to first line drawn.

Lay off on each successive parallel the value for meridian on that parallel and draw lines through points given. Plot the points determined on the projections by squares, and we have a skeleton sheet ready for work.

The balance of work can be done by transit or plane table, or what in most cases will be found of great advantage, the *two* instruments can be used.

If only a perfect *plan* is required, and the available funds are limited, then the plane table will come in to the exclusion of all other instrumenst.

By having a projection as the one described with conveniently located points any street survey however limited, by a little additional field work can be connected with the regular scheme and plotted on to the map, where a complete progress index of the work performed can be kept, and during times when no particular work presents itself the intervening area can be worked up and plotted.

If it is desired to locate a point when the bounds have been lost and local measures are also wanting, take two of the most convenient points as a base, and from this base locate a point as near the true one as can be ascertained.

From the latitude and longitude of the true and assumed point the distance and azimuth are easily found by using the formula already given. Set the instrument over assumed point and lay off the amizuth and distance as computed.

It is a good plan, in order to more securely mark a point, to place an easily distinguished and indestructible substance from three to six feet below the surface, in addition to monument on surface, so that the same shall not be disturbed even if the surface mark is lost.

Such a mark can easily be found by means of the above method.

Where land is valuable, as in the more populous districts, the same methods as already described can be used, but on account of the large

proportion of land covered by buildings it will be found necessary to put in fewer main points, and connect them by a traverse line.

In running a traverse line of this description, start at one of the main points, determined by triangulation, and measure the angle between a second main point and the traverse line, in order to carry the azimuth through the line. Sight to a convenient point, and mark same: drive nails on the line at convenient distances and measure to same.

I have got splendid results by using a hundred-foot Chesterman steel tape, which is standard at 32° Fah.

The best results can only be obtained by using a spring balance with a tension each time of about eight pounds, and by reducing to standard temperature.

At each change in direction, observe angle of deflection by taking six angles with the telescope direct and six with it reversed, with the mean of these for true angle.

At the end of traverse at second main point, observe angle to connect traverse with the regular main points. If the azimuth of two points, as worked through traverse, differs from that by direct determinations, correct each angle by its proportional share of difference, and use the corrected angles for azimuth of traverse lines.

Each point connected can thus be easily worked up, having azimuth and distance given.

The position of second end of traverse line, as worked through traverse line, should be the same as by direct determination; but if there is a slight difference it may be equally distributed over the traverse, so as to adjust each point with reference to main points. In making corrections for temperature, I use the coefficient $\frac{59}{10000000}$ for each degree, and take the logarithm of same: also take the log. of the number of degrees in excess of 32° and add last two logs. for the total correction: a table can easily be made which will materially assist in computing.

Thus, for 40° the log. of 8 would be 0.9030900 added to the log. of $\frac{59}{10000000}$ =4.7708520 would give log. 5.6739420 as the reduction needed to change to standard when the thermometer indicated 40°.

If the measured line is 1,000 feet, we find the log. of the same to be 3.0000000 which, added to above, gives the log. correction as 8.6739420, or .047 feet.

All the errors in measuring are in the same direction and tend to give too short a distance, and with the thermometer varying from ten to twenty or even more degrees one cannot expect to get exact results when neglecting such appreciable corrections.

The final result seems to depend more on the way the instruments are manipulated than on the instruments themselves.

If the Chesterman tape is used and the tables are in metres, as is the case with all those published by U. S. Coast and Geodetic Survey, the result can be reduced to metres by simply adding the arithmetical complement of the logarithm of one metre, expressed in feet, which is 9.4940323, viz.:

1,000 feet logarithm	3.0000000
Correction for 8° temperature	5.6739420
Arithmetical comp. of 1 metre in feet	9.4840323
Correction in metres	8.1579743 or 0.0144

Two of these logarithms are constants, and, if desired, can be combined

together in forming a table, so that a saving of many figures can be made in each problem.

Tables A and B are for making projection, and are condensed from U. S. Coast and Geodetic Survey tables.

A.

TABLE GIVING LENGTHS, IN METRES, OF ARCS OF THE PARALLEL.

Lat.	00 Min.	15 Min.	30 Min.	45 Min.
Deg.				
24	1695.66	1692.37	1689.05	1685.69
25	82.31	78.88	75.43	71.95
26	68.43	64.88	61.31	57.70
27	54.05	50.38	46.68	42.94
28	39.17	35.37	31.54	27.68
29	23.79	19.87	15.91	11.93
30	1607.91	1603.87	1599.79	1595.69
31	1591.55	1587.38	83.18	78.96
32	74.70	70.41	66.09	61.75
33	57.37	52.96	48.52	44.06
34	39.56	35.04	30.48	25.90
35	21.29	16.65	11.98	07.28
36	02.55	1497.79	1493.01	1488.19
37	1483.35	78.48	73.58	68.65
38	63.70	58.72	53.71	48.67
39	43.60	38.51	33.38	28.24
40	23.06	17.86	12.63	07.37
41	02.08	1396.77	1391.43	1386.07
42	1380.68	75.26	69.82	64.35
43	58.85	53.33	47.78	42.21
44	36.61	30.98	25.33	19.66
45	13.96	08.23	02.48	1296.70
46	1290.90	1285.07	1279.22	73.35
47	67.45	61.52	55.57	49.60
48	43.60	37.59	31.54	25.47
49	19.38	13.27	07.13	00.97

B.

TABLE GIVING LENGTH IN METERS OF ARCS OF THE MERIDIAN.

Latitude. Deg.	Min.	Metres.	Latitude. Deg.	Min.	Metres.
24	00	1845.8	37	00	9.4
	30	5.9		30	9.6
25	00	6.0	38	00	9.7
	30	6.2		30	49.9
26	00	6.3	39	00	1850.1
	30	6.4		30	0.2
27	00	6.5	40	00	0 4
	30	6.7		30	0.5
28	00	6.8	41	00	0.7
	30	6.9		30	0.9
29	00	7.1	42	00	1851.0
	30	7.2		30	1.2
30	00	7.3	43	00	1.3
	30	7.5		30	1.5
31	00	7.6	44	00	1.7
	30	7.8		30	1.8
32	00	7.9	45	00	2.0
	30	8.1		30	2.2
33	00	8.2	46	00	2.3
	30	8.4		30	2.5
34	00	8.5	47	00	2.6
	30	8.7		30	2.8
35	00	8.8	48	00	3.0
	30	9.0		30	3.1
36	00	9.1	49	00	3.3
	30	9.3		30	3.4

The distances are all in metres, and are values of one minute. To reduce metres to feet or feet to metres: To logarithm feet add logarithm 9.4840323 to give metres. To logarithm metres add logarithm 0.5159677 to give feet.

Table C gives values for *A B C* and *D* in formulæ for finding difference in latitude, longitude and azimuth, and are condensed same as tables A and B.

C.

Latitude.		Log. A.	Log. B.	Log. C	Log. D.
Deg.	Min.				
23	00........	8.50956029	8.51202588	1.033983	2.24264
	15........	5571	1216	9209	629
	30........	8.50955110	8.51199833	1.044396	2.24987
	45..	4645	8438	9537	2.25338
24	00........	8.50954177	8.51197033	1.054640	684
	15.... ...	3704	5615	9699	2.26023
	30........	8.50953229	8.51194188	1.064723	357
	45........	2749	2748	9705	685
25	00.... ...	8.50952266	8.51191299	1.074653	2.27008
	15........	1779	8.51189839	9563	324
	30........	8.50951289	8368	1.084438	2.27635
	45..	0795	6886	9277	941
26	00........	8.50950298	8.51185395	1.094084	2.28241
	15... . ..	8.50949796	3892	8857	536
	30........	9293	8.51182381	1.103598	2.28826
	45........	8785	0858	8308	2.29110
27	00........	8.50948275	8.51179327	1.112987	390
	15........	7761	7784	7636	664
	30......	8.50947244	8.51176233	1.122256	2.29934
	45........	6723	4671	6848	2.30198
28	00... .. .	8.50946200	8.51173102	1.131412	458
	15........	5673	1521	5949	712
	30........	8.50945144	8.51169933	1.140460	2.30963
	45........	4611	8334	4945	2.31208
29	00........	8.50944075	8.51166728	1.149405	449
	15........	3537	5112	1.153840	685
	30........	8.50942995	8.51163488	8252	2.31917
	45........	2451	1854	1.162640	2.32143
30	00........	8.50941904	8.51160213	7005	366
	15........	1353	8.51158563	1.171347	584
	30........	8.50940801	6905	5670	2.32798
	45........	0245	5239	9970	2.33008
31	00........	8.50939688	8.51153565	1.184252	2 33213
	15........	9127	1882	8509	414
	30	8.50938564	8.51150193	1.192752	2.33611
	45	7998	8.51148495	7972	804
32	00........	8.50937430	6791	1.201176	2.33993
	15........	6859	5079	5360	2.34177
	30........	8.50936286	8.51143360	1.209529	358
	45........	5710	1633	1.213677	534
33	00........	8.50935133	8.51139901	7812	2.34707
	15........	4553	8160	1.221930	875
	30	8.50933971	8.51136414	6032	2.35040
	45..... ..	3386	4660	1.230117	200
34	00...	8.50932800	8.51132901	4189	2.35357
	15.	2211	1135	8245	510
	30........	8.50931621	8.51129363	1.242289	2.35659
	45....	1028	7585	6317	805
35	00........	8.50930433	8.51125802	1.250334	2.35946
	15.	8.50929837	4012	4336	2.36084
	30........	9238	8.51122217	1.258327	218
	45........	8638	0416	1.262305	349
36	00.... ...	8.50928036	8.51118611	6272	2.36476
	15..	7433	6800	1.270227	598
	30........	8 50926827	8.51114984	4172	2.36718
	45........	6221	3162	8105	834
37	00.... ...	8.50925612	8.51111337	1.282028	2.36946
	15........	5001	8.51109506	5942	2.37055
	30.... ...	8.50924390	7672	1.289846	160
	45........	3777	5832	1.293740	262

C.

(CONTINUED.)

Latitude. Deg.	Min.	Log. A.	Log. B.	Log. C	Log. D.
38	00........	8.50923163	8.51103989	7627	2.37360
	15........	2546	2141	1.301503	454
	30........	8.50921930	8.51100290	5372	2.37546
	45........	1311	8.51098435	9233	633
39	00........	8.50920692	6576	1.313087	2.37717
	15........	0071	4714	6933	798
	30........	8.50919449	8.51092848	1.320771	2.37875
	45........	8826	0979	4605	949
40	00........	8.50918202	8.51089107	1.328431	2.38019
	15........	7576	7232	2252	087
	30........	8.50916951	8.51085355	1.336067	2.38150
	45........	6324	3474	9875	210
41	00........	8.50915696	8.51081591	1.343681	2.38267
	15........	5068	8.51079706	7482	321
	30........	8.50914439	7819	1.351275	2.38371
	45........	3809	5929	5067	417
42	00........	8.50913178	8.51074037	1.358854	2.38461
	15........	2547	2144	1.362639	501
	30........	8.50911916	8.51070249	6418	2.38538
	45........	1283	8.51068353	1.370197	571
43	00........	8.50910651	6455	1.373973	2.38601
	15........	0918	4556	7745	28
	30........	8.50909385	8.51062656	1.381516	2.38651
	45........	8751	0755	5285	71
44	00........	8.50908117	8.51058853	1.389052	2.38688
	15........	7483	6951	1.392919	2.38702
	30........	8.50906849	8.51055048	6584	12
	45........	6214	3144	1.400348	19
45	00........	8.50905580	8.51051241	4113	2.38722
	15........	4945	8.51049337	7878	23
	30........	8.50904311	7434	1.411642	2.38720
	45........	3676	5531	5408	13
46	00........	8.50903042	8.51043628	1.419174	2.38704
	15........	2408	1726	1.422942	2.38690
	30........	8.50901774	8.51039825	6711	74
	45........	1141	7924	1.430482	54
47	00........	8.50900507	8.51036023	4255	2.38632
	15........	8.50899874	4125	8030	05
	30........	9242	8.51032227	1.441807	2.38576
	45........	8610	0331	5588	543
48	00........	8.50897978	8.51028437	1.449372	2.38507
	15........	7347	6544	1.453159	467
	30........	8.50896717	8.51024653	6950	2.38424
	45........	6087	2764	1.460746	378
49	00........	8.50895458	8.51020877	4545	2.38328
	15........	4830	8.51018992	8350	275
	30........	8.50894203	7110	1.472159	2.38219
	45........	3576	5230	5974	159

EXPERIMENTAL STUDY COMPARING THE INFLUENCE OF EXPANSION IN SIMPLE AND COMPOUND ENGINES.

By M. O. HALLAUER. Read before the Industrial Society of Mulhouse, December 30, 1878.

(Translated from *Bulletin of the Industrial Society of Mulhouse*, for May–June, 1879, by CHAS. A. SMITH, Member of the Engineers' Club of St. Louis.)

(M. Keller's summary of the following experiments has already been translated and published in the number for November, 1881.)

The comparison of the many experiments made upon Woolf engines, and the engine of M. Hein, with superheated steam, led me to a principle which has been confirmed by the analysis of the compound engines of the French navy. I had stated the conclusion in a paper presented to the Society on the 30th January, 1878.

One can always construct a single cylinder vertical-beam engine, steam

jacketed, with four valves, which shall be at least as economical as the vertical Woolf beam engine, for expansions from 4 to 7, if the clearance does not exceed 1 per cent. of the cylinder volume.

This conclusion is based upon the total work of the engine, supposing a perfect vacuum—in a word, we consider the intrinsic work of the steam itself.

In this memoir I have had occasion to examine the various considerations which serve to establish the superiority of the Woolf system, if one is outside of the experimental domain.

These same considerations I have again found developed under a form nearly identical but very marked in two works, concerning the Woolf engines, with expansion in the small cylinder. The authors there sum up what is generally admitted in favor of the Woolf system, which I will cite literally to permit the reader to appreciate the utility of my previous paper.

The first of these works was published at Rouen by MM. Thomas & Powell, engineers. It contains the experiments made in June, 1876, by M. H. Roland, Engineer of the Nounan Association of Steam Users, and opens thus:

"Double cylinder engines, in which the steam acts successively, are those which produce motive force most economically when well constructed and managed. This advantage is because the small cylinder is only for a moment in communication with the condenser, the large cylinder only is in this condition, and the first action is to withdraw a portion of the force produced from the cooling action of the condenser and the internal condensation which is the immediate consequence.

"The steam arrives at the large cylinder partly expanded, and consequently at a lower temperature than that in the jacket, and is easier warmed and the condensation notably lessened.

"The employment of two cylinders permits us to carry the principle of expansion to its extreme limit with the best economic conditions, the force generated is divided, the efforts better carried and the differences of power between beginning and end of stroke are less than in a single cylinder engine: working with the same admissions there results a smoother operation. Because of the vertical cylinders and perfect equilibrium of the pieces attached to the beam the frictions are reduced and the useful effect is very high. It is to these qualities that the long life of these engines is to be attributed. We can cite some which have worked thirty years and which, after modifications with little cost comparatively, are in perfect order for work and consumption.

"The addition of a 'Comey Governor Expansion Gear,' assures to the engines which are furnished with it a perfect uniformity of speed and economic utilization under all loads."

The second work, published in 1878, in the Annual of the Society of Graduates of the Schools of Arts and Trades, under the title of "Notes Upon Double-Cylinder Engines," contains the results of experiments made by M. Quém, upon engines at St. Remy, constructed by MM. Powell.

"Among the different types of engines actually in use," says M. Quém, "the Woolf, with two cylinders jacketed, in which the steam acts suc-

cessively, is that which gives the best economy in production of motive force.

"In these engines the steam acts first with or without expansion in the small cylinder, then with expansion in the large cylinder. The latter only is in communication with the condenser. By this arrangement a portion of the force produced escapes the cooling action of the condenser and the internal cylinder condensation.

"Finally, because the jackets are connected with the boilers, the expanding steam in the large cylinder is at a temperature below that of the jacket, and is warmed thereby, and the cylinder condensation notably lessened.

"The employment of two cylinders permits the best realization of expansion, which in these Woolf engines can be carried to its limit.

"The difference of force between the beginning and end of the stroke is less in double than in single-cylinder engines; there results smoother working.

"Because of the lesser difference of pressures there are less risks of breaking.

"Finally, leakage of steam by the admission valve is less prejudicial than in single-cylinder engines.

"In Woolf beam engines the balancing of weights reduces the friction, and the useful effect is consequently high.

"We have said that their principle assures to the Woolf engines regularity of speed. That is true, but the regulators which have been applied with the purpose of rendering the speed uniform under variable loads have been far from perfect or from giving the desired results.

"This apparatus, long employed upon single-cylinder engines, is the conical governor and butterfly throttle.

"Not only is the governor throttle unsatisfactory in point of speed, but its operation is bad from the standpoint of economy.

"In effect it operates upon the steampipe, opening or closing a passage.

"There results a throttling which produces an expansion not only useless but prejudicial in the pipe and steam chest, consequently a lowering of initial pressure, which loss of force augments the consumption of fuel.

"It had been desirable to put on Woolf beam engines a variable expansion gear which should be easily put on, which should give these engines great regularity of speed, which should shun the evils of throttling, and which should obtain a greater expansion.

"Valves with lap which had been applied for some years to these engines were a great improvement, but the expansion was fixed and was not sufficient in most cases, and moreover the throttle was retained.

"Comey's variable gear permits us to add to the advantages of the Woolf engines the removal of the throttle, retaining an economic use of steam under all loads."

Of all the foregoing considerations one only is not to be contested: it is as MM. Powell say, that the efforts are better distributed and the differences of force between the beginning and end of the stroke are less than in single-cylinder engines, and the movement smoother. But it should not be concluded from this long-known fact that the useful

effect of double-cylinder engines is high and economical. The brake experiments made by the Mechanical Committee of the Industrial Society of Mulhouse have proved that the friction of the engines absorbs more power in Woolf engines than in single-cylinder engines.

I have already shown in my paper of 1878 what economy can be realized by expansion in a separate cylinder. But the principle which I have stated has raised so many contradictions that our mechanical committee has deemed it prudent to hold itself in reserve when it states in these terms at the close of my work : "Many times already the committee has given its entire approbation to the fruitful experimental method followed by our colleague, and recommends to the attention of all engineers the results of the experiments contained in this work, results which appear to him unattackable. On the contrary, the committee believes it should be less positive in the conclusions of the author ; it desires to see them confirmed by a great number of cases, and above all by varied experience in the widest field." I believed it useful to renew this question with new data, and more, I have added the study of an expansion more or less in the small cylinder of the Woolf engine.

INFLUENCE OF EXPANSION IN WOOLF ENGINES.

Can there be a notable economy in cutting off in the small cylinder of a Woolf engine and expanding, for example, 28 times? Such is the first question which we shall attempt, for it is necessary to verify the consumption reported in each of the experiments which we shall cite, and which fixes the degree of confidence which we shall give them.

It may be useful to recall to our readers, in the interest of the question which occupies us, the passage in my memoir of 1878, which bears upon this question of the influence of expansion (p. 308 of the Bulletin).

The three engines where the expansion was effected in a separate cylinder are ranged in order of their consumption per total horse-power per hour.*

Vertical Woolf engine, 7.112 k (15.4 lbs.) ; horizontal Woolf engine, 7.290 k (15.9 lbs.); compound engine, 7.510 k (16.4 lbs.). But such is also the order of expansion: Vertical Woolf, 7 times; horizontal Woolf, 6 times; compound, 5 times.

The fact that the consumption per total horse-power per hour was increased by changing the cut-off from $\frac{1}{7}$ to $\frac{1}{5}$ was also found with the single-cylinder engine using superheated steam. But we should observe that the reduction of the volume at cut-off causes a reduction of useful work by the engine, and at the same time a relative increase in the back pressure work. In the engine with superheating, and above all in the Woolf engines, this increase of back pressure work not only annuls the economy of a prolonged expansion, but even causes a greater expense. Also the back pressure work passing from 17 to 20 per cent. destroys the economy of the vertical Woolf, when the regulating valve lowering the pressure reduces the work from 347 to 267 horse-power.

The documents which will serve us in the study of expansion are :

1. Experiments made in 1877 at Münster upon a Woolf beam engine.

* The French weights are for a Cheval de Vapeur, translated H. P. English equivalents are in parentheses.

constructed by the house of André Koechlin (really the Alsatian Society of Mechanical Constructions), and figuring in my memoir of 1878.

2. Brake Experiments by the Mechanical Committee of the Industrial Society in 1876 upon a horizontal Woolf by the same builder, and figuring in the Bulletins* (for July, 1877).

3. Experiments made in 1877 by the Alsatian Association of Steam Users upon a vertical Woolf engine at Malmerspach, possessing a variable cut-off in the small cylinder by the same builder.

4. Experiments made upon Woolf beam engines with expansion in the small cylinder, built by MM. Thomas and T. Powell, of Rouen, and tried one in 1877 at St. Remy upon Arne by M. Quém, and the other in 1876 by the Norman Association of Steam Users, this latter running the shops of MM. Fauquet-Lemaitre at Bolbec. The direct results of these experiments upon the Powell engines and that at Malmerspach have been given me by M. H. Walther-Meunier, Engineer of the Alsatian Association of Steam Users. I have checked and analyzed them. The analysis of the other experiments is given in my preceding paper, as I have already said: André Koechlin, Woolf Beam Engine working at Munster, variable power by throttle expansion, 7 times.

CHECK UPON CONSUMPTION, GAUGED DIRECTLY, TAKING AS A BASE THE HEAT GAINED BY THE COLD WATER INJECTED TO THE CONDENSER.

[NOTE.—As these computations are checks, all the French units will be retained, and anything added from other sources will be in ( ).—TRANS.]

I.—Forces des Chevauxs, translated horse-power, I. H. P., 347.16; revolutions per minute, 25.25; net H. P. on brake, 303.46; mechanical efficiency, 87.3 per cent.; proportion of back pressure work to total work, 17.43 per cent.; back pressure on large piston, 0.293 k. (4.2 lbs. per sq. in.) (Boiler press., 67 lbs. above atmosphere.—TRANS.)

Per Single Stroke.

Heat brought by dry saturated steam......	0.9123 k × 654.03 c =	597.19 c
" " " water entrained..........	0.0290 k × 157.47 c =	4.44 c
" " " steam condensed in jackets	0.0884 k × 496.56 c =	43.89 c
Total heat brought to engine...		645.52 c
Heat kept by the steam leaving condenser..	0.9413 × 34.25 =	—32.24 c
	Q_0 =	613.28 c
Heat given to water of condensation.........	29.1072 × 18.05 =	525.38 c
	= Q_1	
$Q_0 - Q_1$ = difference..........................	=	87.90 c
The total work absorbed......................	72.79 c	
The external radiation..............	7. — c	
		79.7 c

Instead of 87.90; or an error of .... $\frac{87.90 - 79.79}{645.52} = 1.25$ per cent.

The heat found in the water of condensation should have been 613.28 c—

* In the table given in JOURNAL for November, 1879, this engine is headed as "Vertical Woolf." The error is in the original.—TRANS.

79.79 c. = 533.49 calories, it was only 525.38 c. consequently too little. The total heat brought to the machine per stroke is 645.52 c. which to be more intelligible we will transform into a weight of dry saturated steam. In accounting for the work of the engine this weight will serve as a unit of comparison for other engines, and will be better comprehended under that form than the number of calories expended per horse-power which it stands in place of.

Consumption of dry steam per stroke, $\frac{645.52 \text{ c}}{654.03 \text{ c}} = 0.98698$ k ; weight of dry steam per total horse-power per hour, 7.112 k ; per I. H. P., 8.614 k ; per net H. P., 9.864 k.

[NOTE.—These weights are from feed water at Q_0 c. I should suggest as divisor the term Q_0.—TRANS.]

II.—I. H. P., 267.85 ; revolutions per min., 25.2 ; net on brake, 226 ; mechanical efficiency, 84.3 per cent.

Proportion of back pressure to total work 20.52 per cent.

" " Back pressure, 0.277 k (3.9 lbs.).

" " (Boiler pressure, 60 lbs. above atmosphere.—TRANS.)

Per Single Stroke.

Heat brought by dry saturated steam......0.7124 k × 652.93 c =	465.14 c
" " " entrained water.........0.0238 k × 153.74 c =	3.66 c
" " " steam to jackets.........0.0794 k × 499.19 c =	36.63 c
" " to engine..	505.43 c
" kept by steam leaving condenser.....0.7362 × 29.10 =	—21.42 c
Q_0 =	484.01 c
" given to injection water........29.3406 k × 14.3 c = Q_1 =	419.57 c
Difference..	64.44 c
The total work.........56.27 c.	
" external radiation 7.— c. Total..........................	63.27 c

$$\text{Error } \frac{64.44 - 63.27}{505.43} = 0.23 \text{ per cent.}$$

The heat found in condenser is too small, it should have been 484.01 — 63.27 = 420.74 c.

The heat brought per stroke is 505.43 c; it represents a consumption of dry saturated steam of

$$\frac{505.43}{652.93} = 0.77409 \text{ k.}$$

Weight dry saturated steam per hour per total horse-power...... 6.945 k

" " " " " " " indicated horse-power, 8.739 k

" " " " " " " net " " 10.357 k

III.—I. H. P. 185.75 ; revolutions per minute, 25.4 ; net on brake, 145.52 ; mechanical efficiency, 78.3 per cent.

Proportion of back pressure work to total work 24.1 per cent.: back pressure on large piston, 0.234 k (3.3 lbs.).

(Boiler pressure 50 lbs. above atmosphere.—TRANS.)

Per Single Stroke.

Heat brought by dry steam	0.5401 k × 650.69 c	=	351.43 c
" " " entrained water	0.0145 k × 146.22 c	=	2.12 c
" " steam condensed in jacket	0.0640 k × 504.47 c	=	32.28 c
" " total		=	385.83 c
" kept by steam leaving condenser	0.5546 k × 23.46 c	=	—12.65 c
	Q_0	=	373.18 c
" found in injection water	30.5688 k × 10.56 c = Q_1	=	322.80 c
	$Q_0—Q_1$	=	50.38 c
The total work	38.71 c		
External radiation	7 c		
			45.71

Error, $\frac{50.38—45.71}{385.83}=1.2$ per cent.

The heat found in the condenser is too little, it should have been $373.18—45.71=327.47$ c.

The heat brought per stroke, 385.83 c; it represents a consumption of $\frac{385.83}{650.69}=0.59295$ k.

Weight of dry saturated steam per hour per	total H. P.	7.384 k
" " " " " " "	Ind. H. P.	9.730 k
" " " " " " "	net H. P.	12.411 k

Uniting in one table the results of these three experiments, we find little difference per total horse-power, only 3.7 per cent. for a change from 183 to 347 horse.

TABLE I.

	I.	II.	III.
Force indicated	347	267	185
Steam per hour per total H. P., kilos	7.112	6.945	7.384
Back pressure work in per cent. of total work	17.43	20.52	24.10
Steam per hour per ind. H. P.	8.614	8.739	9.730
Net work in per cent. ind. work	87.30	84.30	78.30
Steam per hour per net H. P	9.864	10.357	12.411

We note that the cost of a total H. P. is 6 per cent. less for 267 horse than for 185 horse. This economy disappears for the ind. H. P., which is best for 347 H. P.

If these two sorts of consumption follow a distinct law we owe it to the back pressure work, which changes to 17 per cent. from 24 per cent. An analogous cause produces greater differences in the cost of a net H. P. The efficiency changes between 87 and 78 per cent. because of the friction, and we are not astonished to see the cost of a net H. P. differ by 20.5 per cent. It is the practical loss to which we put an engine working at 185 H. P. which can give 347, and is due to the back pressure and friction. But we should not conclude, as is often done, that this loss is due to throttling.

The difference of 3.7 per cent. that we find in the cost of a total H. P. is that due this evil influence, and is very little, or adding the slight increase over Expt. II.

I then legitimately concluded in my last work "that we are led to adopt the most simple regulator, an expansion variable by hand and a governor throttle." When the variations of work are large we can, by

hand, without stopping the engine, change the introduction for the small intermediate differences the governor acts upon the valve. It is well understood that we do not here speak of engines where the force varies nearly instantly, for example, to double. This disposition permits us, as we have seen, to obtain all the benefits of a prolonged expansion, admitting that it gives a notable economy, of which the results of the following experiments will permit us to judge.

WOOLF BEAM ENGINE BY ANDRÉ KOECHLIN, AT MALMERSPACH.

Expansion in the small cylinder. Checks on the gauged consumption from the heat gained by the injection water.

E.—I. H. P., 143.11; revolutions per minute, 26.2; net horse-power, 118.38; efficiency, 82.7 per cent.; back pressure work in per cent. of total work, 18.6; back pressure on large piston, 0.181 k (2.5 lbs.); expansion, 28 times. (Boiler pressure, 67 lbs. above atmosphere.—TRANS.)

Heat brought by dry steam............ 0.3479 k × 654.03 c = 227.53 c
" " entrained water.......... 0.0200 k × 157.47 c = 3.15 c
" " steam to jackets......... 0.0324 k × 496.56 c = 16.09 c
246.77 c
Heat kept by steam leaving condenser..... 0.3679 k × 19.01 c = —6.99 c
" expended...Q_0 = 239.78 c
" rejected in condenser .... 21.8781 k × 9.06 c = 198.21 c
41.57 c
" in work done..28.97 c
" external radiation................................. 4.6 c
33.57 c

$$\text{Error, } \frac{41.57-33.57}{246.77} = 3.2 \text{ per cent.}$$

The heat found in the injection water is too small, it should have been 239.78 — 33.57 = 206.21 c.

The total heat brought to the engine per single stroke is 246.77 c, it represents a consumption of dry steam of $\frac{246.77}{654.03} = 0.3773$ k.

Weight of dry steam per hour per total H. P. .... 6.731 k
" " " " " " " ind. H. P.................. 8.273 k
" " " " " " " net H. P......................10.019 k

C.—I. H. P., 215.7; revolutions per minute, 25.47; net on brake, 185.69; mechanical efficiency, 86.1 per cent.; back pressure work in per cent. of total work, 15.6; back pressure, 0.226 k (3.2 lbs.); expansion, 13 fold; (boiler pressure, 70 lbs. above atmosphere).

Heat brought by dry steam...............0.5338 k × 654.45 c = 349.34 c
" " " entrained water..........0.0304 k × 158.88 c = 4.83 c
" " " steam to jacket...........0.0449 k × 495.57 c = 22.25 c
Total..376.42
Heat kept by steam leaving condenser......... 0.5642 × 23.21 —13.09
" expanded ....Q_0 = 363.33
" gained by injection water...............21.9136 k × 13.48 = 295.39
67.94
" in work done..44.83
" external radiation.. 4.6
49.43

$$\text{Error, } \frac{67.94 - 49.43}{376.42} = 4.9 \text{ per cent.}$$

Heat found in condenser should have been.......363.33 — 49.43 = 313.90
Heat brought per single stroke.......................376.42 c

Represents a consumption of dry steam............... $\frac{376.42}{654.45} = 0.5751$ k

Dry steam per hour per total H. P.............................6.878 k
" " " " " ind. H. P.............................8.149 k
" " " " " net H. P...............................9.465 k

F.—I. H. P., 149.53 ; revolutions per minute, 25.93 : net on brake, 124.74 ; mechanical efficiency, 83.4 per cent.: back pressure work in per cent. total work, 17.5 : back pressure on large piston, 0.175 k (2.4 lbs.) : expansion, 25 fold.

Heat brought by dry steam................0.3652 k × 654.03 c = 238.85 c
" " " carried water............0.0210 k × 157.47 c = 3.30 c
" " to jackets.................0.0350 k × 496.56 c = 17.38 c
259.53 c
" kept by steam leaving condenser.....0.3862 k × 19.43 c = —7.50 c

" expended.. Q_0 = 252.03 c
" given to injection water..........21.2674 k × 9.89 c Q_1 = 210.33 c

" in work done......................................30.51 41.70 c
" " external radiation................................ 4.6
35.11 c

Error, $\frac{41.70 - 35.11}{259.53} = 2.5$ per cent.

Heat found in condenser should have been 252.03 — 35.11 = 216.92 c
Heat expended per single stroke.............................259.53

Represents dry steam................................ $\frac{259.53}{654.03} = 0.3968$ k

Dry steam per hour per total H. P.............................6.821 k
" " " " " ind. H. P.............................8.260 k
" " " " " net H. P...............................9.898 k

D.—I. H. P., 212.92 ; revolutions per minute, 24.83 ; net on brake, 183.67 ; mechanical efficiency, 86.2 per cent.: back pressure work in per cent. of total work, 14.9 : back pressure on large piston, 0.218 k (3 lbs.) : expansion, 13 fold (boiler pressure, 70 lbs. above atmosphere).

Heat brought by dry steam............... 0.5443 k × 654.45 c = 356.22 c
" " " carried water........... 0.0310 k × 158.88 c = 4.92 c
" " to jackets.................. 0.0462 k × 495.57 c = 22.89 c

Total.. = 384.03 c
" kept by steam leaving condenser.. 0.5753 k × 27.02 c = —15.54 c

" expended.. Q_0 = 368.49 c
" found in injection water..... .18.0071 k × 17.07 c = Q_1 = 307.38 c
61.11

" in work done.................................. 45.39
" " external radiation.......................... 4.6
49.99

Error, $\frac{1—49.99}{384.03} = 2.9$ per cent.

Heat found in condenser should have been ......368.49—49.99 = 318.50

Heat brought to engine per stroke .... 384.03 c

Represents dry steam per stroke.......................... $\frac{384.03}{654.45} = 0.5867$ k

Dry steam per hour per total H. P...... .... 6.983 k

" " " " " ind. H P..................... .... 8.210 k

" " " " " net H. P.............................. 9.517 k

This Malmerspach engine is composed of two coupled on the same shaft, and experiments E and C were made on the left, while experiments F and D were made on the right-hand engine. We note that three of these experiments, E, F, D, check to 3 per cent. nearly, but C only to 5 per cent.; however the direct measurement is correct, being sensibly that of experiment D.

TABLE II.

Letter	E.	F.	C.	D.
Expansion	28	25	13	13
I H. P., Ch. de V.	143	149	215	213
Dry steam per hour per total H. P., ks	6.731	6.821	6.878	6.983
Per cent. back pressure work	18.6	17.5	15.6	14.9
Dry steam per hour per ind. H. P., ks	8.273	8.260	8.149	8.210
Per cent. of mechanical efficiency	82.7	83.4	86.1	86.2
Dry steam per hour per net H. P., ks	10.019	9.898	9.465	9.517

Table II. sums our four experiments. The figures which are there compared with Table I. permit us to decide if it is more advantageous to work with the throttle than with a cut-off in the small cylinder, or the reverse. If one is obliged to produce from an engine too small a force, either way is used, but for a careful comparison it is necessary to take if possible the work with the same difference in each. For example, Malmerspach Engine C. and E.: I. H. P., 215 and 143, being 3 : 2, expansions, 13 and 28 : and the Münster engine, II. and III., I H. P., 267 and 185, being nearly the same ratio, expansion 7.

In dry steam per hour per total H. P. there is a difference between 6.945 k, with 267 H. P., and 7.384 k, with 185 H. P. of $\frac{7.384 - 6.945}{7.384} = 5.9$ per cent., in favor of the larger power, both obtained by throttling.

If in the second engine we pass from expansion 13 to 28, the difference in dry steam per total H. P. is $\frac{6.878 - 6.731}{6.878} = 2.1$ per cent. in favor of the lesser power, 143 H. P.; in these limits there is little to chose, for the difference is within the errors of observation.

It seems as if there was an economy of $5.9 + 2.1 = 8$ per cent. ; on the other hand, the 267 H. P. corresponds to the least consumption, 6.945 k, which has been obtained by throttling 1.342 k. at the cut-off (18.8 lbs.). As this only differs $\frac{6.945 - 6.878}{6.945} = 0.9$ per cent. from that for 215 H. P., we conclude, as before, that it is unimportant.

We find ourselves here in the face of a contradiction which we can elucidate later after having given the complete analysis of these engines. For the time we have only to note how the heat of the injection water. checks the consumption and fixes the degree of confidence which we should give to each experiment.

These remarks, based upon the amounts used per total H. P. per hour, only refer to the work of the steam itself in the cylinder. They are not affected by poor vacuum, nor the friction of the engine. The influence of these two elements is only felt when we consider the indicated work and the net work. Thus, in passing from Expt. E, 143, H. P.; expansion, 28, to Expt. C., 215 H. P.; expansion, 13, the consumptions differ per ind. H. P. 1.5 per cent. and per net H. P. 5.5 per cent. This difference is in the reverse order of that for the total H.P.; it shows that practically there is 5.5 per cent. loss in changing from expansion 13 to 28. These same causes, back pressure work and friction, have brought for the Munster engine with fixed expansion 7 stronger effects—increased to 16½ per cent. when throttle causes the work to fall from 267 H. P. to 185 H. P.

Upon the same engine at Malmerspach, and before the application of expansion gear, there had been made an experiment, with the object of defining the economy realized, which we will check as before.

B.—Indicated H. P., 201.64 H. P.; revolutions per minute, 24.18; net on brake, 172.80 H. P.; mechanical efficiency, 85.6 per cent.; back pressure work in per cent. on total work, 16.4; back pressure, 0.235 k (3.3 lbs. per sq. in.); expansion, 6 (boiler pressure, 67 lbs. above atmosphere).

Heat brought by dry steam	0.5823 k × 654.03 c =	380.84 c
" " " carried water	0.0312 k × 157.47 c =	4.91 c
" " to jackets	0.0330 k × 496.56 c =	16.38 c
" " total	=	402.13 c
" kept by steam leaving condenser	0.6135 k × 22.73 c =	13.94 c
" expended	Q_0 =	388.19
" found in injection water	22.6234 × 14.50 = Q_1 =	328.04
		60.15
" in work done	44.14 c	
" " external radiation	4.6 c	
		48.74

$$\frac{60.15-48.74}{402.13} = 2.8 \text{ per cent. error.}$$

The heat found in injection is too small: it should have been 388.19—48.74 = 339.45 c. The heat per stroke is 402.13 c.

It represents $\frac{402.13}{654.03} = 0.6148$ k dry steam.

Dry steam per hour per total H. P.	7.402 k
" " " " " ind. H. P.	8.847 k
" " " " " net H. P.	10.301 k

The result of this analysis, if we consider the engine in good order when the experiment was made, which we will suppose to be the case, compared with experiment C.

B.—Expansion 6. C.—Expansion 13.

$$\text{Per total H. P. } \frac{7.402-6.878}{7.402} = 7.1 \text{ per cent.}$$

$$\text{" ind. H. P. } \frac{8.847-8.149}{8.847} = 8 \text{ per cent.}$$

$$\text{" net. H. P. } \frac{10.301-9.465}{10.301} = 8 \text{ per cent.}$$

by C. over B.

I have valued the friction by the brake experiments of our Mechanical Committee. We shall see how far MM. Powell have obtained the same co-efficients upon their Woolf engines.

HORIZONTAL WOOLF ENGINE, BY ANDRE KOECHLIN, TRIED WITH BRAKE BY THE MECHANICAL COMMITTEE.

I.—I. H. P., 130: revolutions per minute, 39.37: net on brake, 112.08; mechanical efficiency, 86.1 per cent.: back pressure work in per cent. total work, 20.06: back pressure, 0.253 k (3.5 lbs.): expansion, 6 (boiler pressure, 53 lbs. above atmosphere).

Heat brought by dry steam	0.2286 k × 652.46 c =	149.15 c
" " " carried water	0.0079 k × 152.17 c =	1.20 c
" " to jackets	0.0263 k × 500.29 c =	13.16 c
Total		163.51 c
Heat kept by steam leaving condensor	0.2365 k × 26.20 c =	6.19 c
" expended	Q_0 =	157.32 c
" found in injection water	14.6202 k × 9.20 c =	134.50 c
		22.82 c
" in work done	17.45 c	
" in external radiation	3.5	
		20.95 c

$$\frac{22.82-20.95}{163.51} = 1.13 \text{ per cent. error.}$$

The heat gained by injection should have been 157.32 — 20.95 = 136.37 c

Heat per single stroke	163.51 c
Represents dry steam per stroke	$\frac{163.51}{652.46} = 0.2506$ k
Dry steam per hour per total H. P	7.290 k
" " " ind. H. P	9.120 k
" " " net H. P	10.563 k

There is only 1.3 per cent. difference between the consumption per total H. P. and that in experiment B. while for the ind. H. P. there is 3 per cent. in the other direction.

II.—I. H. P., 181: revolutions per minute, 39.67 : net on brake, 161 H. P.; mechanical efficiency, 89 per cent. : back pressure work in per cent. of total work, 17.3 : back pressure, 0.295 k (4.1 lbs.) (boiler pressure, 54 lbs. above atmosphere).

Heat brought by dry steam.............. 0.3134 k × 652.69 c = 204.55 c
" " " carried water........... 0.0134 k × 152.96 c = 2.05 c
" " to jackets..... .... 0.0271 k × 499.73 c = 13.54 c

Total .... 220.14 c
" kept by steam leaving condenser.... 0.3268 k × 23.90 c = 7.81 c
" expended .... Q_0 = 212.33 c
" rejected in injection water..........14.5795 k × 12.58 c = 183.41 c

28.92 c

" in work done 24.12
" " external radiation........................... 3.50

27.62 c

$$\frac{28.92-27.62}{220.14} = 0.6 \text{ per cent.}$$

Heat brought per stroke................................ 220.14 c

Represents dry steam per stroke.......... .... $\frac{220.14}{652.69}$ = 0.3372 k

Dry steam per hour per total H. P.......... .... = 7.328 k
" " " " " ind. H. P......................... = 8.878 k
" " " " " net H. P............... .... = 9.975 k

The consumption per total H. P. is nearly the same as for the preceding experiment, but for the ind. and net H. P. there is a marked improvement by better efficiency, and less proportion of back pressure work, although the vacuum is not so good. This is a fact which we have many times noted.

Finally, that we may not lack generality in our conclusions of the influence of expansion in the small cylinder, I will give the results of experiments made upon the engines constructed by MM. Powell. Little different from the preceding, they are designed with a view to an early cut-off in the small cylinder, but distinguish themselves by the excellent vacuum, 0.100 k of back pressure (1.4 lbs.) on the large piston. We shall see that for 19 expansions the consumption per total H. P. is nearly the same as that we have found for 13 and 28 times.

WOOLF BEAM ENGINE BY POWELL WORKING AT ST. REMY.—EXPERIMENT BY M. R. QUEM.

Expansion, 19 times: indicated horse-power, 137; revolutions per minute, 24.503; net on brake, 107.88 H. P.: mechanical efficiency, 78.7 per cent.: back pressure work in per cent. of total work, 9.9; back pressure, 0.102 k (1.4 lbs.) (boiler pressure, 70 lbs. above atmosphere).

Heat brought by dry steam.......... ......0.3222 k × 654.42 c = 210.85 c
" " " carried water...... ....0.0110 k × 158.80 c = 1.75 c
" " to jackets. . ...0.0412 k × 495.62 c = 20.42 c

Total................ ....233.02 c
Heat kept by steam leaving condenser........0.3332 k × 27 c = —8.99
" expended....... .... Q_0 = 224.03
" found gained by injection water......10.8511 k × 18.24 c = 197.92

26.11

" in work done.................................29.79
" " radiation...... .... 4.50

34.29

$$\frac{26.11-34.29}{233.02} = 3.5 \text{ per cent. error.}$$

Heat found should have been.... ....224.03--34.29 = 189.74

" per single stroke 233.02. Represents dry steam $\frac{233.02}{654.42} = 0.356$ k.

" " hour per total H. P... ....6.840 k

" " " " ind. H. P...7.591 k

" " " " net H. P...9.702 k

The consumption per total H. P. of this last experiment, made with 19 expansions on the Powell engine, is exactly between the two experiments E and C, made upon the Koechlin engine with expansions of 13 and 28. These three consumptions are 6.731 k. 6.840 k. 6.878 k. differing among themselves 1.4 per cent. Upon different engines they prove, between expansions of 13 and 28, how little the effect of expansion is upon the good work of steam. The very good vacuum of the Powell engine, 0.102 k (1.4 lbs.), gives it practically a marked superiority over the Koechlin engine, expanding 13 times, a circumstance remarkably exceptional for a Woolf engine, which demands to be justified by more numerous experiments: it loses only 9.9 per cent. in back pressure work, in the place of 15 per cent., and we shall not be astonished to find there is $\frac{8.149 - 7.591}{8.149} = 6.8$ per cent. in its favor.

We had wished to join to these results those that were obtained by M. H. Roland upon the same Powell engines, tried at Bolbec: but, as we shall see, their exactitude leaves much to be desired, and we only remark the excellent vacuum and the error committed, 9.9 per cent., which causes us to set aside the results.

(The computations are not transcribed.—TRANSLATOR.)

THE PULLMAN SEWERAGE.

BY BENEZETTE WILLIAMS, MEMBER OF THE WESTERN SOCIETY OF ENGINEERS.

[Read June 5, 1882.]

The town of Pullman is situated on the west shore of Lake Calumet, 5 to 6 miles west of Lake Michigan. It is 14 miles south of Chicago, on the line of the Illinois Central Railroad. It has been built by Pullman's Palace Car Company in connection with their Chicago Works. Besides the Pullman car shops there are now in operation at Pullman the Allen Paper Car Wheel Works, the Union Foundry and Pullman Car Wheel Works, the Dunning Steel Horseshoe Works, the Spanish American Curled Hair Factory and large brickyards belonging to the Pullman company. The Chicago Rawhide and Belting Works are to be built this season, and in the near future the Illinois Central Railroad shops and the shops of the New York, Chicago & St. Louis Railroad are to be built on adjoining lands.

The industries now in operation have about 2,500 men employed. In building and various outside work, in addition to those in the shops, there are about 1,200 men employed.

On the 1st of June there were living at Pullman 625 families, with a population of 4,500. The population is limited by the number of houses ready to occupy.

Buildings which will accommodate 824 families are nearly completed and enough for 570 more have been begun. It is fully expected that in one year from now the population will be as much as 8,000 or 10,000.

The buildings are of brick and have been built in the most substantial manner.

Other objects than durability have been aimed at by its founder, from whom Pullman takes its name.

It is intended that the town shall be unique in more than one respect. Beside healthful homes, provisions are made for many comforts and enjoyments usually out of reach of the artizans and mechanics.

It is a munificent effort on the part of concentrated capital, not only to furnish houses for workmen, but to provide for all the various needs of a civilized and cultured community. Stores and markets, the theater and the library, as well as churches and school-houses have been made only secondary to dwellings and the workshop. The Esthetics of architecture and landscapings are made prominent features. The grouping of buildings and trees to produce a pleasing effect, is studied as diligently as the arrangement of machines in the shop.

It is in this town, built upon land that two years ago was a wild prairie, that the system of sewerage which I wish to describe is in use.

In a late letter to the *Sanitary Engineer*, Robert Rawlinson defines his position, with reference to the separate and combined systems of sewerage, in these words: "As to town sewering and house draining in general, I do not wish to be considered wedded to any special system, combined or separate. There are cases in which I would exclude surface water—I have done so—and there are cases in which I would take in surface water, as I have done." To any one but a specialist this position would seem to be the only correct one.

In the sewerage of certain towns the propriety of adopting the separate system is apparent. In other cases its superiority to the combined system is not so evident. Pullman is a place for which the separate system is particularly well adapted, and for the following reasons:

The site of the town is almost level, much of it not more than 7 or 8 feet above the lake, making it impossible to obtain a gravity discharge to any other body of water than Lake Calumet. This lake is shallow, ranging from 1 to 8 feet in depth. It is about 3 miles long and 1½ miles wide. It drains a small area, and is con-connected with Lake Michigan by the Calumet river. The river, however, which drains a much larger area than the lake, does not run through the lake, but is connected therewith by a small channel, through which the water flows from the lake to the river, or from the river to the lake, according to the varying conditions of winds and floods.

In the absence of any adequate means of purifying itself, Lake Calumet is wholly unfit for a receptacle for sewage.

The small elevation of Pullman and the great distance to Lake Michigan renders a gravity discharge thereto impossible.

When a town can not get rid of its sewage by a gravity discharge, the alternative is to use pumps. When pumps have to be relied upon, the exclusion of rain water from the sewers becomes almost a necessity. And when the surface water can readily be carried off by a system of

drains made for that purpose only, as has been done at Pullman, it adds strength to the reasons for fixing upon the separate system, which in this case was adopted for the reasons given, independently of its supposed sanitary merits.

The question of disposal, however, was not one that could be settled by the force of conditions. In selecting the place for, and deciding upon the manner of, disposal, there was room for a greater range of opinion and judgment, though even in this the question was soon narrowed down to two parts.

Lake Michigan could be reached with a pipe 6½ miles long, and by pumping, the sewage could readily have been discharged therein. The only practicable alternative was land purification in some shape.

It was found that suitable land could be had 3 miles away, the title to which had been acquired by the Pullman Land Association. Estimates showed that a pipe could be laid to this land. A farm sufficient to dispose of the sewage of 10,000 people prepared, and suitable farm buildings erected for a less outlay than would be incurred in laying a pipe to Lake Michigan. It was believed that the farm could be made to pay expenses, and the interest upon the money actually expended upon the farm proper, which would make the scheme of land purification considerably cheaper than the lake disposal, to say nothing of the objection felt to further contamination of a body of water that is in places already overcharged with filth.

The plan of sewerage was determined upon, and the laying of the sewers begun, in August, 1880—soon after the writer was employed as engineer of the Water and Sewerage Works for Pullman.

Six months later, in February, 1881, the method of disposal was decided by the adoption of the sewage farm project.

October 18, 1881, the system was put into operation on starting the sewage pumps.

The system of sewerage is designed to reach a tract of land 2 miles long and an average of something more than a mile wide, comprising about 1,500 acres of land.

To drain this district three mains have been provided, which center at the water tower, which is also the sewage pumping station.

The mains leading from the north and from the west are 18 inches in diameter and the one leading from the south is 15 inches in diameter. These mains are laid with a grade of one foot in 1,000 feet.

The 9 inch laterals are laid with grades varying from 3 to 4 feet per 1,000 feet, and the 6 inch laterals with grades of from 4 feet to 6 feet per 1,000 feet, according to circumstances. The maximum grade in each case being the one used in all but special cases.

The minimum grades used are sufficient to give a velocity of 2 feet per second. A rather low velocity, it is true, but the best that could be obtained without large additional expense.

At the pumping station the mains are about 16 feet below the general grade of the town. The extreme ends of the 6 inch sewers in the alleys being about 6½ feet below the yards in rear of the houses.

The ground in which the sewers are laid is a hard, tough, drift clay.

Man-holes are 160 feet apart on the mains and generally 200 feet apart

on all the laterals. Being built also at every change of grade and direction. They are covered with a ventilating iron cover, with a trough or channel under the openings to catch dirt.

It was thought best to put the man-holes closer on the mains than on the laterals in order that a scraper might be used to remove deposit which it was feared would accumulate, owing to their slight inclination. In the smaller sewers, flushing and the pill being relied upon.

In one instance only has it been found necessary to use a scraper. This was caused by a heavy rain which washed dirt into the sewer during construction.

The flushing appliances consist in connections of the water mains with the 9, 12, 15 and 18 inch sewers, and of automatic flushing basins on the house drains, which flush the 6 inch laterals.

The house drains from the sewers to the flushing basins are 6 inches in diameter. The horizontal pipe connecting the water-closets are 4 inches in diameter and are connected outside of the basins.

The sewage from sinks and wash bowls is usually carried outside of the houses separate from water-closet sewage, the former being admitted to the flushing basins, and used for flushing. These basins serve the purpose of grease traps, in preventing the accumulation of grease in the sewers outside of the basins. The siphons are so constructed that the grease and other scum is carried out of the basin when a flush occurs. The grease being cold and carried along with a strong current cannot adhere to the sides of the sewers. When the basins are properly built all the grease can be kept out of the basins by this means.

The houses being of one ownership and management, from four to six houses are connected with one basin for the sake of economy.

Another very effective method of flushing the mains, though not originally suggested as such, is by closing a valve in the pipe connecting the sewers with the sewage reservoir at the pumping station, until sewage has accumulated in the mains to as great a height as admissible, when by suddenly opening it excellent results are obtained.

In all there has been laid at Pullman up to June 1, 1882, the following amounts of sewers of the various sizes, exclusive of house connections, viz:

4,356	lineal feet of	18-inch	sewers.
3,176	" " "	15	" "
680	" " "	12	" "
3,600	" " "	9	" "
12,000	" " "	6	" "
500	" " "	4	" "

Or, 24,312 lineal feet in all, which, with 130 man-holes, has cost about $50,000. This, of course, includes the most expensive part of the work, which was done, much of it, under very unfavorable circumstances, in very hard ground.

In all cases outside of houses, in mains, laterals and house drains, salt-glazed, vitrified clay pipe of the Akron make have been used.

Within the houses, soil pipes are of iron, and were put in by the Durham House Drainage Company of Chicago. The vertical soil pipes are

wrought-iron, coated with coal-tar varnish, put together with screw joints: and the horizontal pipes are cast-iron, with lead joints.

The vertical pipes are 3 inches in diameter, and the horizontal pipes 4 inches in diameter. The horizontal pipe connects with the outside sewer, without a trap. The vertical pipe runs through the roof in all cases full size.

In the most of cases, each soil pipe has two or more water-closets connected with it. A pipe placed in a partition wall between two houses generally takes the soil for both houses. In cases of three-story flats, one pipe frequently has six closets connected to it.

By these departures from the usual size of pipes and the usual manner of setting closets, a great saving in cost has been effected without inconvenience of any kind.

Out of several hundred 3-inch soil pipes that have been in use from two to eight months, perhaps six or eight cases of stoppage have occurred.

In every instance the stoppage was due to obstructions that got in during construction, and never to the use of a small sized pipe. The results would unquestionably have been the same had 4-inch pipes been use.

The sewerage system drains into a sewage reservoir in the base of the water tower. The whole width of the foundation of the tower having been excavated to a depth of 30 feet and all the space up to the grade of the sewers, not occupied by the walls being used for storage.

This holds about 200,000 gallons.

Increased storage capacity can be had when needed by excavating a side chamber. It is expected that the present capacity will suffice for 8,000 population.

Ventilation of the sewage reservoir is secured by means of eight flues lined with 12-inch sewer pipe, built in the buttresses of the tower and opening at a height of 165 feet, and also by a 20-inch pipe leading to the chimney of the car shops. The ventilation thus secured is perfect.

The reservoir is arched over with groined arches, forming a floor for the sewage and water pumps, 10 feet below the surface of the ground.

The sewage pumping engines are direct acting compound condensing, with piston pumps. Each having a capacity of 2,500,000 gallons in 24 hours.

They were made with the special object of getting machines which would pump everything to be found in sewage either of an ordinary or an extraordinary character. It was considered desirable to avoid screening or settling the sewage at the pumping station. All the sediment which collects in the reservoir by incidental settling, is from time to time washed loose with a hose and passed off with the liquid sewage.

In order to pump the sewage without screening, a rubber valve of special make is in use. Without taking time to describe the valves now, it will be sufficient to say that thus far they are working to great satisfaction. Cotton waste, large cloths, sticks, and blocks of wood have passed through the pumps frequently; indeed many of such substances are daily passing, without injury or inconvenience.

Barring the riveting of two parts of the rubber together, where they were at first imperfectly joined, no repairs have been needed, and there is nothing to indicate aught but a long life for the valves.

The pumps were made by the Cope & Maxwell Manufacturing Co., of Hamilton, Ohio.

The least amount of sewage during the latter part of May for twenty-four hours was, by pump measurement, 450,000 gallons. Of this I estimate that one-third is sub-soil water that finds its way into the sewers by soaking through the brickwork of the man-holes and occasional open joints, but mainly from a sewer that has lately been put in where water is admitted from unbuilt man-holes. The spring having been very wet, a large amount of water has been admitted through these incompleted man-holes.

The sewage is conveyed to the farm by a 20-inch cast-iron main, nearly 3 miles long. The farm end of this main connects with a closed screening tank, by means of which all material that will not pass through a screen of ½-inch mesh is intercepted. The tank is 6 feet in diameter and 24 feet long, made of ¼-inch boiler iron. It is set vertically, with its lower end high enough above the floor to admit of a wagon being driven under it. The material intercepted by the screen is lodged in the lower part of the tank, from which it is removed from time to time.

On leaving the tank the sewage passes through a pressure-regulating valve, which limits the pressure that comes upon the pipes leading to the fields to about 10 pounds. As an additional precaution against high pressure an overflow pipe is provided, which will absolutely, under all conditions, prevent the pressure from rising above the limit. This pipe comes into play occasionally when the pumps are started suddenly without giving the valve time to act. The valve is purposely made to act slowly, in order to avoid the influence of pulsations in the engines, and irregularities from other causes.

The action of the tank and valve are best understood by an examination of the accompanying drawing:

A pressure on the interior of the thin steel discs above the valve raises the plunger and closes the ports through which the sewage passes. If the pressure falls the ports open gently. Vibrations of the valve from sudden changes of pressure are prevented by a plate between the valve and the steel discs, through small holes in which the sewage has to pass in order to increase or diminish the pressure on the discs.

The upper part of the tank above the screen is an air chamber, and answers the usual purpose of such an adjunct in preventing shocks from irregularities in the pumps, or by the sudden stopping of the flow of sewage.

The tank and valve are housed in and can be kept warm to prevent freezing in cold weather.

The reason for introducing the pressure-regulating valve between the screening tank and the field is to make it possible to distribute sewage safely through clay sewage pipes under pressure.

The main distributing pipe is 18 inches in diameter. From this main four lines of 9-inch pipes, 315 feet apart, are laid across a 60-acre field. Every 320 feet on each line of 9-inch pipe a hydrant is set, thus giving one

hydrant to each 2½ acres or thereabouts. On an 80-acre tract which is now being underdrained, it is probable that two lines of 12-inch pipes will be used to distribute the sewage. This tract lies more favorably for surface distribution than the one prepared last year, and it is believed that fewer lines of pipes and hydrants will be sufficient.

The pipes laid last year for distributing the sewage were of Akron make with socket joints. The first pipe ordered were made with 3-inch sockets, but it was afterwards found that sockets of ordinary depth would make a tight joint.

Before laying the pipes it was thought best to make a test as to whether weak or cracked pipe could be detected by ordinary inspection. An application of hydraulic pressure developed the fact that no inspection possible to apply could be relied upon. Many pipes that looked rough and full of fire cracks, that would ordinarily be rejected, were found to be among the best, while, on the other hand, the clearest ringing and best appearing pipes were often the poorest. These results made it necessary to apply the test generally.

The test applied was 20 pounds pressure per square inch.

It was soon found that this pressure would break too large a proportion—about two-fifths—of the 18-inch pipe, so it was decided to lay the main in concrete without testing. The 9-inch pipes stood the test better, about one pipe in four being broken in the operation. This loss could be stood and still the sewer pipe be much the cheapest thing that could be used for the purpose.

It was a noticeable peculiarity of the pipes that 75 per cent. of those that failed, broke below 10 pounds.

The bed of concrete around the 18-inch main was from 4 to 6 inches in thickness. The bottom generally made of Utica cement, mortar, and broken stone, while for the top and sides Portland cement was used.

The 9-inch pipes were laid with stiff Portland cement, mortar mixed with an equal quantity of sand.

A hemp gasket was tried at first, but it was soon found that the quickest and best way in every respect to make a joint, is to form a bed of mortar on the lower half of the socket and insert the next pipe, then with the trowel to apply the mortar to the annular space on the top, until it is forced through on to the inside. Out of 7,500 feet of pipe laid in this manner there has been found but one case of defective joints, and this was caused by a heavy rain during the laying.

The general conclusion from this experience thus far, in the use of clay sewer pipes, to carry fluids under pressure, is that for light pressures of about 10 pounds, the smaller sized pipes are well adapted to the purpose, if proper care is used in selecting them and in making the joints as they are laid.

I consider it by no means certain that sizes up to 18-inch cannot be profitably used, as I think that the lot of pipe of this size that we had was of rather poor quality.

Thin pipe seemed to give better results than thick ones.

The system of under drainage on 60 acres prepared last year, consists of one main under drain from six inches to twelve inches in diameter, of

sewer pipe, laid north and south, and emptying into a ditch that discharges into Lake Calumet: and of parallel lines of common tile, 2 to 4 inches in diameter, laid to an average depth of 3½ feet, and an average distance of 40 feet apart. The tile were laid with strips of tarred paper tied around the joints. Ten feet of tile were strung on a pole at the side trench, the joints wrapped, and the whole ten feet put in place at one operation.

As to any of the general results of sewage farming, it is too soon to speak from experience upon the Pullman farm. The ground was covered with a tough sod, much of it a coarse wild grass, and was plowed late last fall. The sod is still so tough that it is impossible to put it in proper shape for irrigating the crops.

Then the spring has been so backward, owing to wet and cold, that no kind of crops are much advanced in this region.

Difficulty is also being experienced by the grass starting to grow upon the land where sewage has been applied during May.

It is intended to under-drain 12½ feet apart, a portion of land best adapted to sewage purification, for filter beds—to be used as a safety valve, when, if applied to ordinary crops, sewage would be an incumbrance. Upon these filter beds some of the coarser kinds of crops can be grown.

As soon as the farm has really been fairly started—which, owing to the reasons given, cannot be before next year—I see no cause to doubt the success of the enterprise.

There is one feature of the system of direct pumping of the sewage at Pullman, which may be of interest.

The pumps, screening tank and pressure-regulating valve are so arranged and are so dependent one upon another that notwithstanding the use of clay pipes for distributing the sewage the workmen on the farm can control the quantity of sewage received with perfect safety. They can close and open hydrants to any desired extent and vary the amount of sewage discharged almost as they please without danger or inconvenience. The operation is this: If the sewage is flowing at any given rate and one or more outlets be closed the effect is to partially close the pressure-regulating valve, by a slightly increased pressure on the distributing pipes, and to transmit from the valve through the force main an increased pressure to the pumps, which are provided with a steam regulator that reduces the pressure of steam admitted to the cylinders.

In order to avoid all possibility of injury to pipes or pumps in this operation, a stand-pipe with two overflows is provided at the pumps, as well as one at the regulating valve, so that there is an absolute guarantee against damage from the failure of any mechanical appliance.

The stand pipe connected with the pump main in the tower is—measuring from datum—54 feet high to the first overflow, and 90 feet high to the second overflow. These overflows are connected with a pipe which returns the sewage to the reservoir below the pumps. So that if every outlet is closed at the farm the pumps could continue to run with freedom.

Should the pressure regulating valve fail to perform its functions, the overflow pipe will then protect the clay distributing pipes from undue pressure.

The general features of sewerage, and of sewage disposal adopted at Pullman had the sanction of Mr. E. S. Chesbrough, who was consulted by the Pullman Company.

In carrying out the work I have been ably assisted by Mr. Edgar Williams in the preparation of plans, and the execution of the work at Pullman, and by Mr. E. T. Martin in laying drainage and distributing pipes at the sewage farm.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

MAY 17, 1882:—A regular meeting of the Society was held at 7:30 P. M., President Doane in the chair; sixteen members and two visitors present.

The record of the last meeting read and approved.

Mr. Samuel M. Felton, Jr., and Mr. Charles H. Swan were elected members of the Society

The following short communication was presented from Mr. J. H. Danforth :

It being claimed by an inspector of axles that a correct comparison of several drop tests was made by multiplying together height of drop and weight and comparing results, the writer was called upon for an opinion in the matter.

The following formula for energy being applied and results compared, showed the above rule to be incorrect, and as the writer has not seen its application to this purpose elsewhere noted, it may be worth mentioning: Energy of a moving body $= \frac{Mv^2}{2} = \frac{Wv^2}{2g} = \frac{Wv^2}{64.4}$. (Rankine, A. M., p. 499.)

With points of support to the tested piece at a constant distance apart, and a short table of velocities, the energy of blows from different heights and weights can be readily compared.

Mr. Dexter Brackett read a paper describing some experiments made on the Boston water-works, with the Deacon Waste Water System. A portion of one of the meters was exhibited, and the method of using it fully explained.

[*Adjourned.*] S. E. TINKHAM, Secretary

JUNE 21, 1882:—A regular meeting of the Society was held at 7.30 P. M., Mr. C. W. Folsom in the chair, seventeen members and one visitor present.

The record of the last meeting was read and approved.

It was voted that the next regular meeting be held on the third Wednesday in September.

The announcement was made of the appointment by the President of the following committee to solicit advertisements for the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES: Messrs. H. A. Carson, Wm. S. Barbour and C. W. Lunt.

Mr. A. W. Locke was proposed for membership by Messrs. Turner and Hardy.

Prof. Channing Whitaker read a paper describing "An Efficient Apparatus for Printing by the Blue Process," and Mr. Wm. E. McClintock one entitled, "Notes on Co-ordinate Surveying."

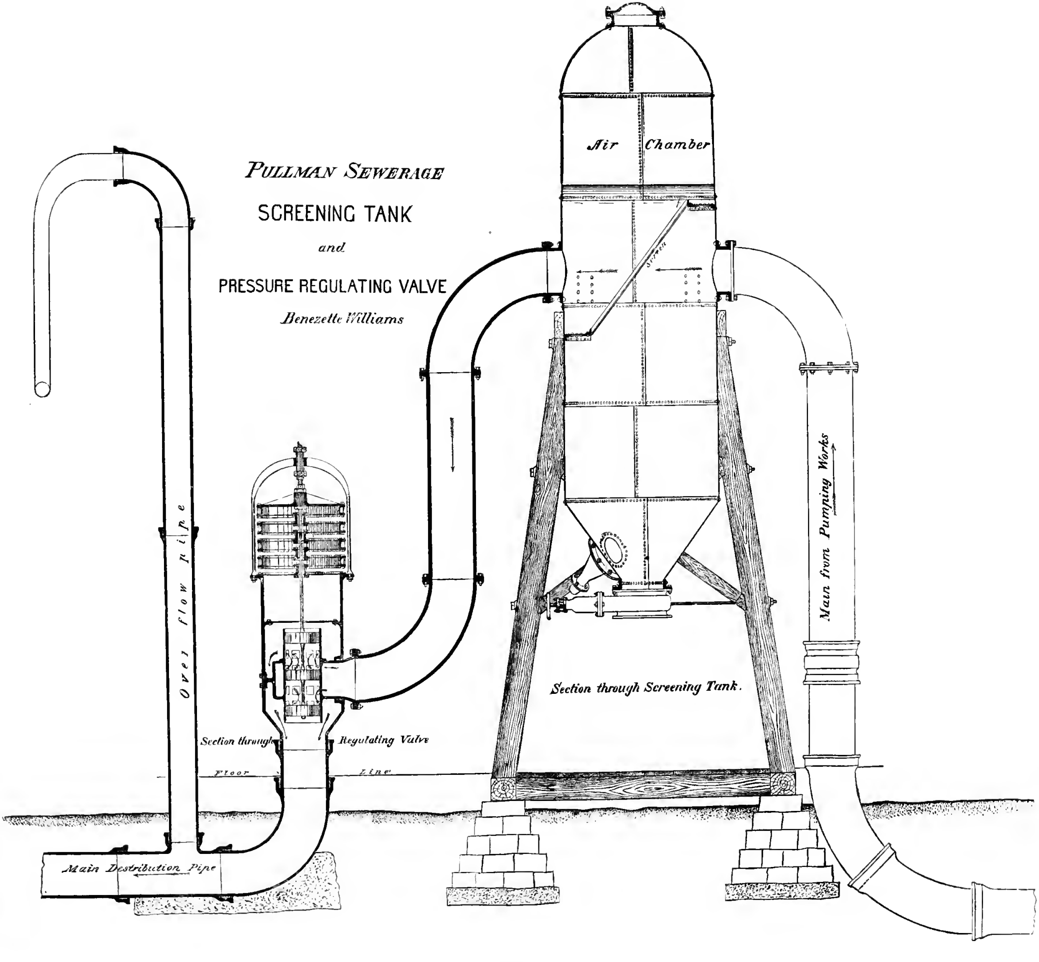
Mr. G. W. Blodgett made some observations on Electric Railways. The disadvantages of the ordinary railway are obvious, such as :

(1) The weight of the locomotive and tender is a dead loss, and moved at a great expense, and carry no useful load. This weight sometimes amounts to 50 per cent. of that of the remainder of the train. It is concentrated on a few points, and entails heavier, stronger and much more costly bridges and tracks, and much more labor and expense in maintenance.

(2) It produces large volumes of smoke and cinders. These and the noise of escaping steam is disagreeable and annoying to passengers and the public in general.

(3) Danger to life and property from the explosion of boiler or from fire.

(4) The small percentage of useful effect of the coal consumed compared to that



PULLMAN SEWERAGE
SCREENING TANK
and
PRESSURE REGULATING VALVE
Benezette Williams
Air Chamber
Screen
Over flow pipe
Main from Pumping Works
Section through Screening Tank.
Section through Regulating Valve
Floor Line
Main Distribution Pipe

which might be obtained under a stationary boiler, owing to large surface exposed to radiation, and general unfavorable conditions of consumption. Coal is often not completely consumed.

In electric propulsion we have the following advantages:

(1) *Every pair* of wheels can be utilized for motive power, or in stopping the train.

(2) By suitably adapting the speed of the generator to that of the electro-motors, as much as 70 per cent. of useful effect of the generators can be converted into motion.

(3) Experiment shows that with an electro-motor as high a rate of efficiency as one horse-power may be obtained per 50 lbs. dead weight of motor.

(4) By properly arranging the connections a train running into a section already occupied by another train will be brought to an immediate standstill, and will remain at rest until the preceding train has passed out of that section.

Some practical disadvantages in the use of electricity for this purpose are:

(1) The large expense of installation.

(2) Loss of current by leakage. The prevention of this is by better insulation, but this is at greater expense both in first cost and in maintenance. The leakage can be reduced to not much more than 10 per cent., even on long lines, by appropriate means.

(3) Danger to life if laid on streets, or indeed on the surface of the ground. Safer for elevated roads than for surface roads.

(4) Inconvenience of repairs. These must be carefully made, and without interruption of continuity of circuit.

(5) A break of a serious nature would bring every train to a stop, none of which could be moved until the repairs were effected.

A brief description of Siemens' railway, exhibited at Berlin, 1879, and London, 1881, was given. In this road the current was led to the train by a third rail or wire laid between the others, and returned through the ordinary traffic rails.

In the tramway at Paris, the current was conducted to and from the car by two wires overhead, on which ran a small, light carriage attached to the car by wires, and through which the current was conducted to the motor.

Brief reference was also made to experiments of Profs. Ayrton and Perry, but fuller description of their proposed ingenious system was postponed to a future meeting.

[*Adjourned.*] S. E. TINKHAM, Secretary.

WESTERN SOCIETY OF ENGINEERS.

TUESDAY, JUNE 6, 1882:—The 148th regular meeting was held at 4 P. M., Vice President Cregier in the chair.

The minutes of the preceding meeting were read and approved.

Mr. Charles Lapham, of Milwaukee, Wis., Assistant Engineer Chicago, Milwaukee & St. Paul Railway, made application to be admitted as an Associate, endorsed by Messrs. Conover, Weston and Morehouse.

In accordance with a resolution passed at the preceding meeting, the Secretary read the following:

REPORT ON STANDING AND SPECIAL COMMITTEES.

Committee on Public Library.—At the 112th meeting Messrs. Weston (Librarian), Wright and Chesbrough were appointed a committee to prepare a list of books to be recommended by the Society for purchase by the Public Library. At the 113th meeting the committee reported. The report was accepted and the committee continued. At the 114th meeting the committee reported progress.

Committee on Seal.—At the 112th meeting, October 5, 1880, a committee,

consisting of Messrs. B. Williams, French and Morehouse, was appointed to report upon a device for a seal, and upon the several forms prescribed by the By-Laws.

The committee reported, at the 115th meeting, that the prescribed forms had been prepared and had been approved by the Trustees. By vote of the Society, the forms were adopted.

At the 142d meeting, owing to the inability of Mr. French to act, the chairman appointed Mr. MacHarg a member of the committee.

At the 144th meeting the committee reported progress, and at the 146th meeting requested an extension of time.

At the 147th meeting, May 16, 1882, the committee presented a design for a seal, which was adopted, and the committee was directed to procure a seal for the use of the Society.

Committee on Membership.—At the 116th meeting, December 7, 1880, a committee, consisting of Messrs. Weston, B. Williams and Fitz Simons, was appointed to confer with the Secretary in relation to increasing the membership of the Society. At the 138th meeting the Secretary, in his annual report for 1881, stated that two circulars had been issued by this committee.

Committee on Papers.—At the 116th meeting, December 7, 1880, a committee, consisting of Messrs. MacHarg, F. W. Clarke and C. J. Bates, was appointed to report upon a plan for the purpose of securing papers to be read before the Society.

The committee reported at the 119th meeting, and the recommendations of the report were adopted. A resolution was passed that the committee should be continued, to report upon any matter relating to the subject. At the 123d meeting the President appointed Messrs. F. W. Clarke, C. J. Bates and John Zellweger as Committee on Papers. At the 124th meeting, Mr. Clarke having declined to serve, Mr. MacHarg was appointed a member of the committee.

Committee on Abstracts.—At the 117th meeting it was voted that a committee of three be appointed to prepare abstracts of professional articles published in periodicals to present from time to time for discussion. The President announced that the names of this committee would be given at the next meeting.

Committee on Weights and Measures.—At the 122d meeting it was voted that a committee of five be appointed on the subject of Weights and Measures. At the 124th meeting Messrs. Greeley, Latimer, C. J. Bates, Fitzsimons and Cole were appointed members. At the 144th meeting Mr. Greeley reported that no report had been decided upon.

Committee on Prize Paper.—At the 123d meeting it was voted that a committee be appointed to consider and report upon the question of an annual prize paper. At the 124th meeting Messrs. Liljencrantz, B. Williams, Rust and MacHarg were appointed as this committee. At the 146th meeting the committee reported and the report was accepted.

Committee on Permanent Quarters.—At the 123d meeting it was voted that a committee, consisting of the President and four other members, should be appointed to consult with the Public Library Board, and report upon obtaining permanent quarters. At the 124th meeting Messrs. Sooy Smith, Cregier, Cole and MacHarg were appointed members.

Committee on Diploma.—At the 142d meeting the Committee on Seal, Messrs. B. Williams, Morehouse and MacHarg, were appointed a committee to prepare a form of diploma.

Committee on Portraits.—At the 142d meeting Messrs. B. Williams, Fitz Simons and Liljencrantz were appointed a committee to report upon the matter of obtaining portraits of the President and ex-Presidents of the Society. At the 146th meeting the committee reported; the report was received and its recommendations adopted. The committee was instructed to carry out the recommendations of the report.

The report was received, and it was voted to take up its consideration *seriatim*.

Mr. Wright, of the Committee on Public Library, made a final report, and, upon motion, the Committee was discharged.

Mr. MacHarg, for Committee on Seal, reported progress in carrying out the directions of the Society.

It was voted that the Committee on Papers be continued.

It was voted that the President be requested to appoint members of the Committee on Abstracts.

It was voted that the Committee on Weights and Measures be requested to report at the first meeting in July.

Mr. Liljencrantz gave notice that he should ask action at some future time on the report of the Committe on Prize Paper.

It was voted that the Committee on Permanent Quarters be requested to report at the first meeting in September.

It was voted that the Committee on Diploma be requested to report at the first meeting in August.

Mr. Williams reported that the Committee on Portraits were proceeding to carry out the directions of the Society.

Mr. Williams, Manager of the Association of Engineering Societies, made the following report and recommendation :

REPORT.

The expense of publishing the first five numbers of the Journal of the Association of Engineering Societies has been....................................$890.87
Less receipts from miscellaneous sources......... .... 94.98

Leaving net cost..$795.89

The revenue collected from the societies for entrance fees, and the first assessment of $1.50, has yielded about $750.

The Board of Managers have concluded not to make a formal assessment until a meeting is held, which it is the expectation to hold this month.

In the meantime, we will need some friends to bear the expense of the publication.

The other three societies have made payments on account, and it is desirable that our society should do likewise.

It may be well to state that nothing has been received yet from advertising, as it was thought best to make no collections until the first six months had expired. From this source the Association will net over $400 per year.

I, therefore, move that the Secretary and Treasurer be instructed to pay to the Association of Engineering Societies, on account of the publication of the Journal of the Association, the sum of $100, to be applied on the next assessment made by the Board of Managers.

The motion, as proposed, was adopted.

Mr. Liljencrantz read a description of the seal recently adopted.

Mr. Benezette Williams read a paper on "The Pullman Sewerage," descriptive of the system recently put in operation at the city of Pullman.

After a discussion of the paper, the meeting adjourned.

L. P. MOREHOUSE, Secretary.

To the President and Members of the Western Society of Engineers:

In accordance with a request, made by the Society at the 147th regular meeting, the undersigned has prepared a description of the various emblems, embodied in the design for a seal, intended for the Society and adopted at the above mentioned meeting, which description is hereby respectfully submitted.

It has been the aim of the designer to indicate by appropriate emblems, as far

as space and other circumstances would allow, the different branches of engineering represented in the Society, and of some of the fundamental branches of science on which the manifold works of our profession are based.

Thus, the suspension bridge, the sounding party, and "Polaris," the guiding star for those who seek the true meridian, and its assistant, the "Dipper," are emblematical of the Civil Engineers. The Mining Engineers are represented by some of their working tools, the sledge, the pick and the drill, while the castle and the cogwheel are the universally adopted emblems of the Military and Mechancal Engineers respectively.

These several designs are inclosed in the four fields produced by the construction of the famous 47th problem of Euclid, probably the most prominent and useful problem in geometry, wherefore this has been deemed the most appropriate representative of that important branch of science.

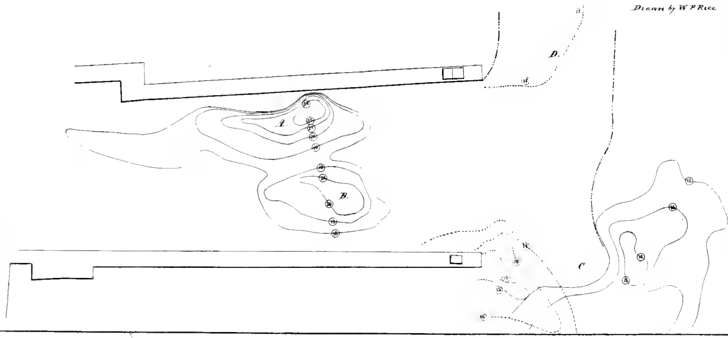
Algebra and the higher mathematics, the calculus, are also represented by well known signs pertaining to these branches.

Finally, the motto. "*Per ardua ad metam*," which translated means, "Through difficulties to the aim," intended to indicate the universal purpose of all the different branches of the Engineering profession, has been given in *Latin*, not to intimate thereby that this is the language with which the representatives of our profession are *most familiar*, but in the first place to get a comprehensive expression in a condensed form, secondly, to make it more *professional in appearance*, and finally because, if I am permitted to use a common phrase, "They all do it."

Respectfully, G. A. M. LILJENCRANTZ.

Pl. 1.

Drawn by W P Rice

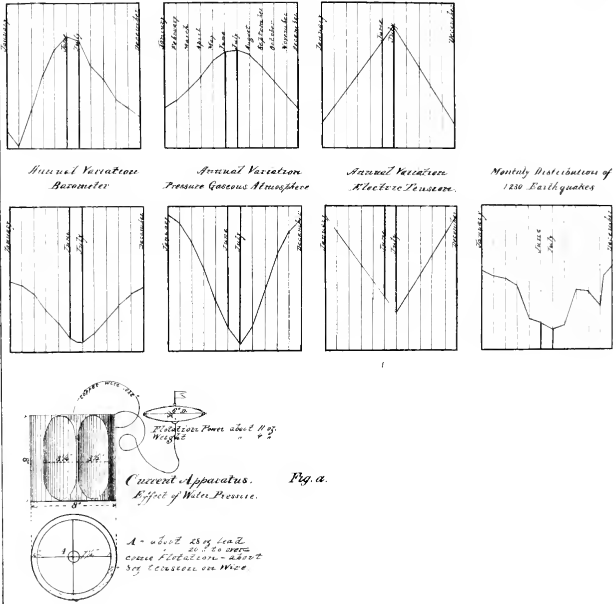


Pl. 2.

Drawn by W P Rice

Pl. 3.

Compiled by W.P.Rice



ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. I. JULY, 1882. No. 9.

DESCRIPTION OF THE APPARATUS USED BY THE FRENCH ENGINEERS TO DETERMINE THE CO-EFFICIENT OF ATTRITION.

I.—OF PAVING-STONES.

BY PROF. WM. WATSON, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read December 21. 1881.]

The principle of the apparatus used to determine the co-efficient of paving stones may be briefly stated thus: 1st. Take a paving stone cut into a regular form, place it upon the face of a horizontal emery wheel and apply a definite pressure to the stone. 2d. Take another block of the same size of the stone to be tested and place it also upon the wheel, at the same distance from the axle as the first, and apply to it the same pressure. Set the wheel in motion and at the end of a certain time calculate the amount of attrition by the loss of weight of the two specimens, taking into account their respective densities.

It is evident that since the two specimens are similarly placed, it is unnecessary to consider the velocity, the regularity or the duration of the rotation, as the circumstances producing the attrition are the same in both cases.

The standard adopted for comparison is a good Yevette sandstone, and its co-efficient is assumed as unity.

The co-efficient of attrition of porphyry, for example, is the ratio of the loss of volume of the porphyry to that of the Yevette sandstone.

The research of the co-efficient of attrition is very simple.

The specimen to be tried is cut into the form of a parallelopipedon of the same size and shape as that of the standard, and its weight and density carefully determined.

The specimen and the standard are then placed upon the wheel *M*, Fig. 1, and exactly the same pressure is applied to each by means of the levers *l l'*; the wheel is then turned until an appreciable wearing has

taken place. The specimen and the standard are again weighed, and the loss of each noted.

Denote by L the loss of weight of the standard :
Denote by L the loss of weight of the specimen :

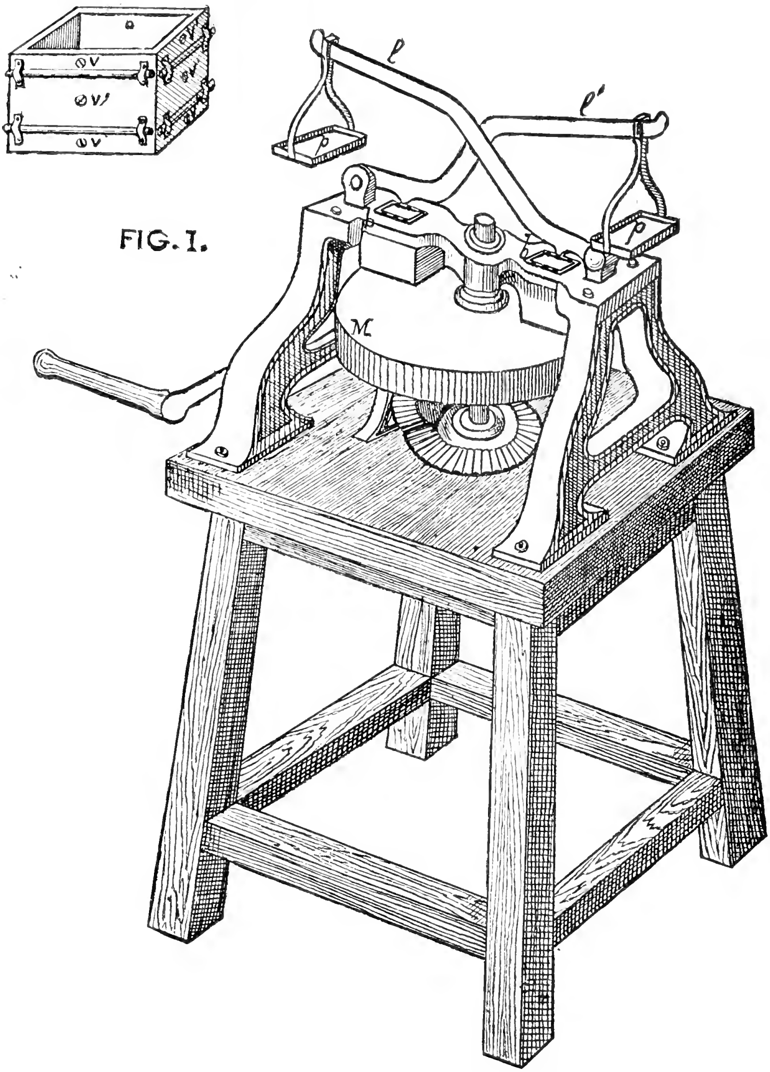


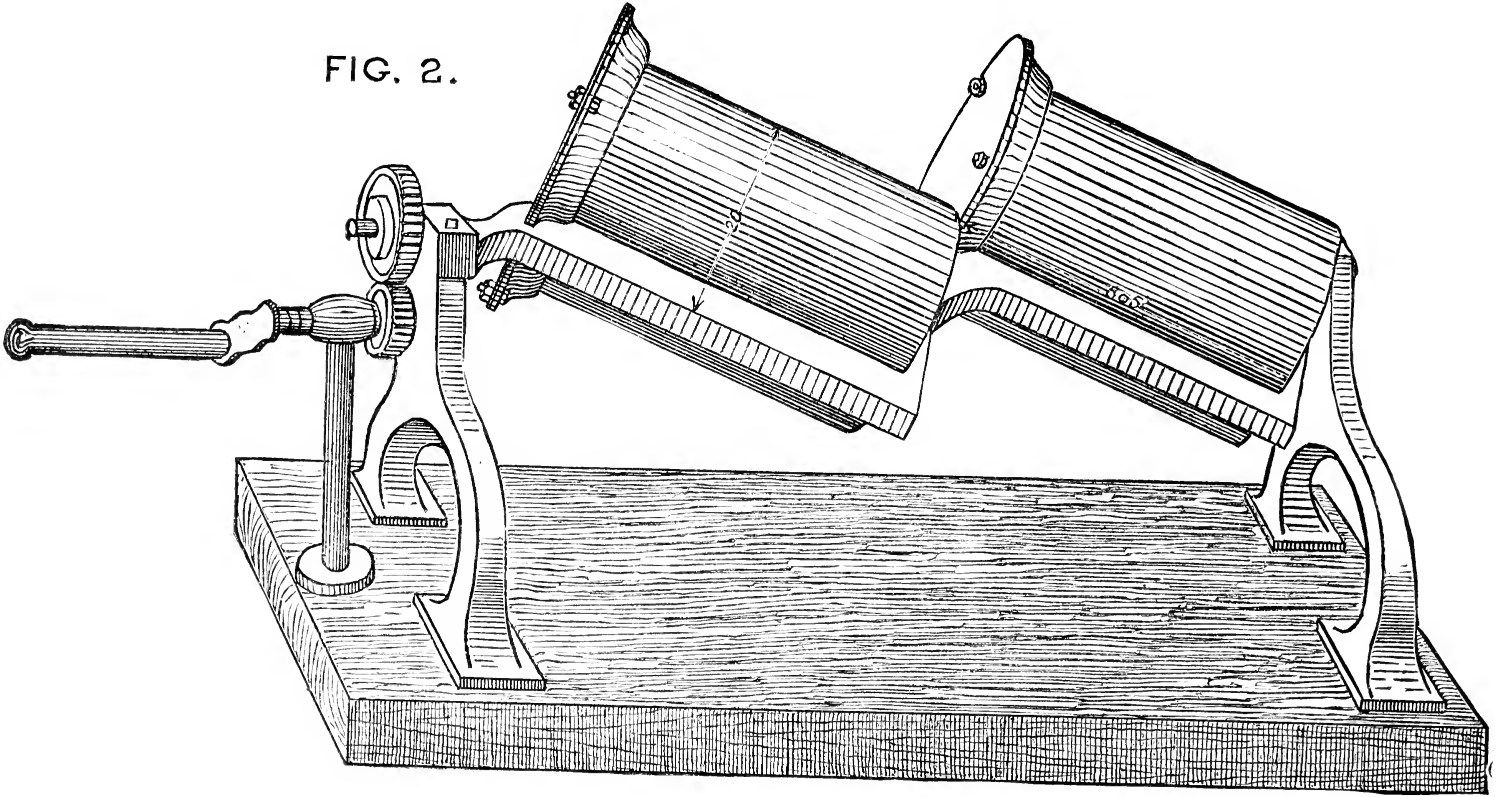
FIG. I.

Denote by D the weight per cubic meter of the standard :
Denote by D' the weight per cubic meter of the specimen.

Then the co-efficient of attrition will be $= \dfrac{L'\,D}{L\,D'}$

This very simple process gives us an exact knowledge of the value of

FIG. 2.



any material as a pavage, for it shows not only its resistance to wearing, but an examination of the polished surface indicates whether in time it will become slippery for horses passing over it.

Taking the best quality of sandstone as unity we have as the co-efficient of attrition:

For flint or quartz from	0.25 to 0.88
Porphyry	0.46 to 0.76
Sienite	0.88
Limestone	5.00
Granite	2.11 to 4.30
Brick	6.

II.—OF ROAD METAL.

To determine the co-efficient of attrition of road metal, two iron cylinders (Fig. 2) of equal size are mounted on an axle oblique to their axes of figure.

Specimens of the standard material (porphyry) are put into one cylinder, and into the other, pieces of the stone to be tried. The same weights are put into the cylinders and also pieces of the same size.

The two cylinders are then turned simultaneously, and the detritus formed by the friction of the materials is collected.

It is evident that the harder the material the less will be the amount of detritus.

The ratio of the loss of weight of the specimen to that of the standard will be the co-efficient of attrition.

A certain quality of porphyry has been taken as the standard of comparison:

Porphyry (of Myenne)	1
Mill stone	1.838
Pudding stone	3.557, etc., etc.

The friction produced by the rolling of the materials in the cylinder is somewhat analagous to the friction of the stones in a macadamized road against each other under the influence of a rolling load.

But these essays, though very useful to give an approximate idea of the value of an unknown specimen, cannot replace completely practical experience.

There is in reality another element in macadamized roads to be considered besides the hardness of the road metal, viz., the cohesion of the metal when packed together by rolling.

Thus, flint which is very hard, when tested by the above apparatus, makes an inferior road metal, for when it has sharp corners, they break off, and when it has a rounded form it easily disintegrates.

Finally, we have to consider the gangues in which the materials are enveloped. As is well known, mill-stone road metal becomes very sticky.

M. Duval had the idea of wetting the detritus, in the above experiments, of making it into a paste and trying it with Vicat's needle.* He found the Voutré porphyry, and the Han sandstone detritus required about the same time to set, while that of the millstone required one and one-half as much time.

This result coincides remarkably with what precedes. In reality, the

*Vicat's Needle.—The cement is said to be set where it will bear a weight of 0.30 k. on a knitting needle, having the end filed flat, and whose diameter is 0.12 c.; area of end = 0.0113 c. q.; the load per square centimeter is 26.5 k.

Voutré porphyry having a co-efficient of 1.00 and the Han sandstone 1.12, while millstone varies from 1.43 to 1.838.

Great advantage accrues from the employment of very hard materials, notwithstanding their high price. Porphyry, for example, costs one and one-half the price of mill-stone, but the wear is less in the same proportion, and it is besides less muddy, which is an important consideration in a city like Paris where enormous sums are annually spent to remove the mud and dust.

EXPERIMENTAL STUDY COMPARING THE INFLUENCE OF EXPANSION IN SIMPLE AND COMPOUND ENGINES.

By M. O. Hallauer. Read before the Industrial Society of Mulhouse, December 30, 1878.

(Translated from *Bulletin of the Industrial Society of Mulhouse*, for May—June, 1879, by Chas. A. Smith, Member of the Engineers' Club of St. Louis.

THIRD PAPER.

The results of the experiments C, D, E, F [see Journal of the Association of Engineering Societies, vol. 1, No. 8], of the Malmerspach engine (André Koechlin) with that on the St. Remy engine (Powell), prove to us the small influence of an expansion from 13 to 28; in these limits the total H. P. cost varies only 2 per cent. in one case from the other. This fact acquired we shall seek to render an account of the following anomaly, which we have already noted, between cost per total H. P. of experiments B and C of the Malmerspach engine. With expansion 6 and 13 we found 7 per cent. difference, which should represent the economy of expansion 13; but we should be too high, for it does not agree with the figures of C, D, E and F, nor with the results of the Powell engine. This difference is more when compared with II., 267 H. P., of the Münster engine, expanding 7 times; which gives the least cost as 6.945 k per total H. P., when the expansion 13 gives 6.878—difference of 1 per cent. We shall see if analysis will show us the cause of this irregularity.

ANALYSIS OF EXPERIMENT III.

Account of heat and cooling by condenser, per stroke:

Weight of fluid in small cylinder	0.5776 k
" " dry steam at cut-off	0.4553 k
" " water " " " (21.17 per cent.)	0.1223 k
" " " carried over	0.0145 k
" " " condensed up to cut-off	0.1078 k
Heat given to iron .... 0.1078 k × 516.77 c =	55.70 c
Weight of fluid in large cylinder	0.5830 k
" " dry steam at end of stroke	0.5399 k
" " water at end of stroke (7.39 per cent)	0.0431 k
Internal heat at the end of admission U_0	—290.12 c
Internal heat at the end of stroke U_1	322.01 c
$U_0—U_1$	31.89 c

Heat given by jacket	32.28	c
" " " condensation in small cylinder	55.70	c
" furnished during expansion	56.09	c
" absorbed by total work of expansion	35.61	c
" radiated externally	7.00	c
	42.61	

56.09 — 42.61 = 13.48 c = R_c, cooling by condensor being 3.5 per cent. of the heat brought to the engine.

The final internal heat compared with the heat gained by the injection water furnishes a check on R_c.

Internal heat at end of stroke U_1	322.01	c
Heat of back pressure work	+ 12.29	c
" remaining in cushion	— 14.92	c
" " after condensation	— 12.65	c
	306.73	c
" gained by injection water	322.80	c
R_c	16.07	c

The other method gave R_c = 13.48 c : the error is only

$$\frac{16.07 - 13.48}{385.83} = 0.67 \text{ per cent.}$$

ANALYSIS OF EXPERIMENT II.

Account of heat and cooling by the condenser :

Weight of fluid in small cylinder	0.7697 k
" dry steam at cut-off	0.6603 k
" water at cut-off (14.21 per cent.)	0.1094 k
" " carried over	0.0238 k
" " condensed	0.0856 k
Heat given to iron up to cut-off	43.40 c
Weight of fluid in large cylinder	0.7650 k
" dry steam at end of stroke	0.7237 k
" water at end of stroke (5.39 per cent.)	0.0413 k

Internal heat at cut-off U_0	415.57	c
" " end of stroke U_1	432.15	c
$U_0—U_1$	— 16.58	c
Heat furnished by jacket	36.63	c
" " " condensation in small cylinder	43.40	c
" " during expansion	63.45	
" absorbed by work of expansion	49.80	
" external radiation	7.	
	56.78	

$R_c = 6.65$ c : R_c is a loss of $\frac{6.65}{505.43} = 1.32$ per cent. of total heat per stroke furnished engine.

Check on R_c :

Internal heat at end of stroke U_1	432.15 c
Back pressure work	+ 14.53 c
Heat remaining in cushion	— 15.13 c
" " " fluid after condensation	— 21.42 c
	410.13 c
" gained by injection water	419.57 c
R_c	9.34 c

The other method $R_c = 6.65$; $\frac{9.44-6.65}{505.45} = .55$ per cent.

ANALYSIS OF EXPERIMENT I.

Account of heat and cooling by condenser, R_c :

Weight of fluid in small cylinder per stroke	0.9847 k
" " dry steam at cut-off	0.8254 k
" " water at cut-off (16.17 per cent)	0.1593 k
" " " carried over	0.0290 k
" " " condensed at cut-off	0.1303 k
Heat given to iron at cut-off	65.25 c
Weight of fluid in large cylinder	0.9691 k
" " dry steam at end of stroke	0.9051 k
" " " water at end of stroke (6.6 per cent.)	0.0640 k
Internal heat at cut-off	U_0 525.79 c
" " " end of stroke	U_1 543.19 c
U_0—U_1	= 17.40 c
Heat furnished by jacket	43.89 c
" " " iron small cylinder	65.25 c
" " during expansion	91.74 c
" in total work done during expansion	62.85 c
" of external radiation	7.00 c

$R_c = 21.89$ c ; per cent of heat furnished, 3.38.

Check on R_c :

Internal heat at end of stroke	U_1 543.19 c
Back pressure work	+ 15.37 c
Heat remaining in cushion	— 14.60 c
" " " fluid after condensing	32.24 c
	511.72 c
" gained by injection water	525.38 c
R_c	13.66 c

The other method gave 21.89 :

$$\frac{21.89 - 13.66}{645.52} = 1.26 \text{ per cent. error.}$$

HORIZONTAL WOOLF, 130 H. P.: EXPANSION, 6.

Account of heat and cooling by condenser R_c:

Weight of fluid per stroke in small cylinder	0.2500 k
" " dry steam at cut-off	0.2220 k
" " water at cut-off (11.2 per cent.)	0.0280 k
" " " carried over	0.0079 k
" " " condensed at cut-off	0.0201 k
Heat given to iron at cut off	10.30 c
Weight of fluid in large cylinder	0.2506 k
" " dry steam at end of stroke	0.2372 k
" " water at end of stroke (5.34 per cent.)	0.0134 k
Internal heat at cut-off U_0	137.85 c
" " " end of stroke U_1	141.48 c
$U_0 - U_1$	—3.63 c
Heat furnished by jacket	13.16 c
" " " iron above	10.30 c
" " during expansion	19.83 c
" absorbed during expansion, total work	14.38 c
" external radiation	3.50 c

R_c = 1.95 c.; per cent. R_c of total heat furnished, 1.19 c.

Check on R_c:

Internal heat at end of stroke	141.48 c
Back pressure work	+ 4.38 c
Heat retained in cushion	— 7.43 c
" " " condenser	— 6.19 c
	132.24 c
" gained by injection water	134.53 c
R_c	2.26 c

$$\frac{2.26 - 1.95}{163.51} = 0\ 1 \text{ per cent. error.}$$

HORIZONTAL WOOLF, 181 H. P.: EXPANSION, 6.

Account of heat and cooling by condenser R_c:

Weight of fluid per stroke in small cylinder	0.3459 k
" " dry steam per stroke at cut-off	0.3082 k
" " water per stroke at cut-off (10.8 per cent.)	0.0377 k
" " water carried over	0.0134 k
" " water condensed at cut-off	0.0243 k
Heat given to iron	12.24 c
Weight of fluid in large cylinder	0.3478 k
" " dry steam at end of stroke	0.3324 k
" " water at end of stroke (4.5 per cent.)	0.0154 k

Internal heat at end of admission U_0	192.68	c
" " " " stroke U_1	198.80	c
$U_0-U_1=$	—6.12	c
Heat furnished by jacket	13.54	c
" " " iron above	12.24	c
" " during expansion	19.66	c
" absorbed during expansion, total work	14.50	c
" lost, external radiation	3.50	c

$R_c=1.66$ c; per cent. of heat furnished, $\frac{1.66}{220.14}=0.75$.

Check on R_c:

Internal heat at end of stroke U_1	198.80	c
Back pressure work	+ 5.10	c
Heat retained in cushion	—10.03	c
" " " condenser	— 7.81	c
	186.06	c
" gained by injection water	183.41	c
R_c	2.65	c

The other method gave 1.66 c.

$$\frac{2.65-1.66}{220.14}=0.45 \text{ per cent. error.}$$

[The error appears to be $\frac{2.65+1.66}{220.14}=1.9$, as the check on R_c gives —2.65, as the injection has gained less heat than was rejected.]

Experiment II. on the Münster engine and I. on the horizontal engine are little different as to proportions of final water and heat lost by the cooling due the condenser R_c. We have stated the difference $\frac{7.290-6.745}{7.290}=$ 4.7 per cent. between the cost of a total H. P. It is due part to the difference between 6 and 7 expansions, but more to the strong compression in the vertical engine, which partially annuls the effect of the clearance.

The experiments of which the analysis will follow do not offer the precision of the two preceding series, of which the consumption check within one per cent., nearly: also we will neglect the weight of fluid in the clearance when establishing the internal heats U_1 and U_0 and the difference U_0-U_1. I did not proceed thus until I had rendered an account of the error which is committed.

With engine 267 H. P., $U_0-U_1=16.58$ c: when the clearance is taken into account, $U_0-U_1=19.80$ c; when it is neglected, an error of $\frac{19.80-16.58}{505.43}=0.6$ per cent. For the horizontal engine, U_0-U_1 will be 3.44 in place of 3.63 c, an error of $\frac{3.63-3.44}{163.51}=0.1$ per cent.

Our second manner of procedure is thus justified above all in practical experiments which check within 3 per cent. only, but we add again that this approximation is very satisfying and conducts us to some very remark-

able results. [The error is always one way, and the comparisons are very accurate].

MALMERSPACH ENGINE, EXPERIMENT A—201 H. P., 6 EXPANSIONS.

Heat account and cooling by condenser R_c:

Weight of fluid in small cylinder	0.6135 k
" " dry steam at cut-off	0.5350 k
" " water " " (12.8 per cent.)	0.0785 k
" " " carried over	0.0312 k
" " " condensed at cut-off	0.0473 k
Heat given to iron	24.09 c
Weight of fluid in large cylinder	0.6135 k
" " dry steam at end of stroke	0.5429 k
" " water " " " " (11.5 per cent.)	0.0706 k
Internal heat at end of admission	U_0=384.86 c
" " " " " stroke	U_1=327.69 c
$U_0—U_1$	7.17 c
Heat furnished by jackets	16.38 c
" " " iron	24.09 c
" " during expansion	47.64 c
" absorbed " " by total work	34.60 c
" lost by external radiation	4.60 c

R_c =8.44 c., being $\frac{8.44}{402.13}$=2.1 per cent. of the heat furnished.

Check on R_c:

Internal heat at end of stroke U_1=	327.69 c
Back pressure work	8.61 c
Heat retained after condensation	—13.94 c
	322.26 c
Heat gained by injection water	328.04 c
R_c	5.68 c
By the other method	8.44

$\frac{8.44—5.68}{402.13}$=0.7 per cent. error.

This engine differs from the horizontal one by a larger proportion of terminal water, 11.5 per cent. in place of 5.3 per cent. The cost of a total H. P. is also greater by $\frac{7.402—7.290}{7.402}$ = 1.5 per cent.

The expansion 6 and the conditions of regulation are the same, but we see that the jackets are not working in the same manner as that of the horizontal engine condensing 10 per cent. of the steam, while the second only 5.1 per cent.; there is then from this fact a loss which changes the internal heat and increases the heat lost by the cooling due the condenser.

Compared with Expt. II., 267 H. P., Expt. B gives us 4.7 per cent. less condensation in the jackets and a less cushion, which brings the Malmer-

spach engine $\frac{7.402-6.945}{7.402}$ = 6.1 per cent. worse than the Münster engine.

All these considerations should indicate where the economy really is rather than to a large expansion commencing in the small cylinder.

OBSERVATIONS ON THE MOUTHS OF LAKE TRIBUTARIES.

By Walter P. Rice, Member of the Civil Engineers' Club of Cleveland.

[Read April 11. 1882.]

While this paper may seem somewhat in the nature of a collection of isolated facts, yet they are all links in the great chain of causes governing the regimen of the mouths of lake affluents, and as such are worthy of attention.

GAUGING THE CUYAHOGA RIVER.

During March last I conducted a series of observations on the volume and currents of the Cuyahoga, under direction of Col. J. M. Wilson. These observations, although limited, afford interesting data. I used the current apparatus adopted by Gen. Ellis. It is made of tin, and consists of two parts: the principal or submerged float being an annular ring 8 inches high and 8 inches extreme diameter, with an air space of $\frac{1}{2}$ inch, making inner diameter $7\frac{1}{2}$ inches; the other or surface float is an ellipsoid 6 inches diameter by $1\frac{1}{2}$ inches depth. The two parts are connected by a copper wire .036 of an inch diameter, attached to the centre of figure of the submerged portion by means of two brass cross-wires 4 inches from the top. Lead is applied to overcome the flotation, and in sufficient excess to bring about 8 ounces tension on the wire.

Observers who have used this apparatus state that it is apt to assume a hexagonal condition from effects of water pressure in depths varying from 20 to 30 feet.

The instrument I had constructed must have been of an inferior quality of tin, for it partially collapsed under pressure at a depth of only 9 feet, and started two sides of what would constitute an almost perfect heptagon if completed. See Fig. *a*.

Currents.—The river was gauged a little south of the U. S. Life Saving Station, the bottom being very uniform and the greatest care taken to insure accurate results. The result is embodied in the following table:

VOLUME AND CURRENTS OF CUYAHOGA AT MOUTH.

Date.	Maximum current.	Volume of water.	Remarks.
	Ft. per min.	Cub. ft. per m.	
Feb. 15, 1882....	49.5	91,063	Wind S. W., max. vel., 19 miles.
Feb. 20, 1882....	168.7	366,307*	Wind N. E., max. vel., 9 miles.
March 3, 1882 .	27.1†	56,653	Wind W., max. vel., 13 miles.

* Note.—Rainfall of 0.8 inches, Feb. 19.

† On March 3 the maximum velocity is only 5.4 inches per second, a velocity insufficient to hold sand in suspension.

The term mouth, as applied to a river, is most certainly a happy expres-

sion. Take any of the rivers emptying into Lake Erie for instance, we find at the mouth respiration as in man. Irregular breathing, if we may be allowed to use the comparison, a flux and reflux of breath, currents and reverse currents at certain seasons, and under certain conditions, pulsations as frequent and irregular as those of a sick man. As an illustration, in attempting to obtain a set of observations with regard to the discharge of the Cuyahoga, February 11, 1882, the following was the result of four observations in the central sub-section of the river.

During an interval of 45 minutes, with a rise .075 of a foot in the water evel the mid-depth velocity declined 75 per cent., the loss of velocity being 50 per cent. for the last 15 minutes of the interval. Any rise of water from winds off the Lake backs the water up in the river and produces just such results. For this reason to obtain the best results in gauging such a river, the section selected should be far enough removed to be independent of the movements of the Lake.

The experiments on the Cuyahoga developed the fact of the existence of an eddy at *R*. Pl. 2. The stream suffers a contraction at the Lake Shore & Michigan Southern Railway draw-bridge with corresponding increase of head or velocity. After passing this point there is a decrease of velocity and consequent loss of head, and the corresponding mechanical effect is employed in working on the elements of the more slowly moving current below, and in the formation of an eddy. The abutment takes up about 25 feet of the waterway. The divergence of the currents takes place about 22 feet from the dock, and the eddy as determined agrees with and affords a fine practical confirmation of the laws governing the dynamics of fluids.

The submerged float being set for a depth of 9 feet was released at the mouth of the Cuyahoga and followed the path marked out on Pl. 2; the wind shifting between east and southeast with a velocity of ten miles an hour. As will be seen by the diagram after leaving the protection of the pier, the curve of the current is normal to the direction of the wind force. This shows the strong inclination of the river to flow to the eastward even with a strong opposing force. As an approximation the average velocity of the current over the path indicated was about 9.1 feet per minute.

DYNAMICS OF LAKE ERIE.

Under this head we shall notice the movements of the lake as all such changes of level necessarily affect all tributaries in the vicinity of their mouths.

Effect of Long Continued Winds.—The rise and fall of the water from this cause is sometimes very great; winds blowing off shore lowering the water level, and winds blowing off the lake heaping up or raising the level. The action of the water is sometimes several hours in advance of the coming wind, and offers sure data for predictions. At the upper end of Sandusky Bay I have observed the water fall to such an extent that tugs which were in active operation on Friday, November 12th, 1880, had to be propped up on Sunday the 14th, this being the effect of a three days' blow from the southwest. The water having fallen between four and five feet. I have noticed almost as great a fall in Maumee Bay which is very similar in its characteristics. I have also noticed a change of level,

partly due to westerly wind and partly to contraction, between the river and lake at Port Clinton within 1000 feet of the end of the pile revetment. The water on the west or river side of the revetment being 3⅛ inches higher than on the east or lake side.

Annual Fluctuation.—There is an annual fluctuation of the water level of the Lake in harmony with the laws of evaporation and rainfall: high water occurring in June or July and low water in January or February. These months seem to represent the extremes of all atmospheric phenomena, including even earthquakes. The wonderfuly unity of action of all these forces is shown by the series of annual profiles, Pl. 3. The amount and character of the annual fluctuation of the Lake is dependent upon the atmospheric condition.

Pulsations or "Seiches."—Besides the decided change in water level directly due to the action of winds on the lake, there are certain periodic pulsations or throbbings of the lake and mouths of affluents certainly not due to this cause. We must search elsewhere for an explanation. The solution which occurred to me is as follows: Conceive Lake Erie to be the reservoir or bulb of a gigantic barometer, of which the affluents for a certain distance from the mouths constitute the stems. Here we have a most sensitive barometer, the readings of which may be taken from the water gauge. The rarity or density of the atmosphere pressing upon the lake's surface being the direct cause of the pulsations. I believe the water gauge to be the true index to this barometer, and if we had sufficient data we could determine the condition of the atmosphere from the reading of the gauge. These pulsations as a general rule are small. I suspect from the reason that the storm centres avoid the lake, going north or south of it; but in the case of a rapidly moving storm area over the lake I have no doubt these harmless pulsations would develop into a great change of level, and that it would be as much if not more dependent upon the varying pressure of the atmosphere than upon the attendant storm-winds. I offer this as explanatory of the tidal waves sometimes seen on the great lakes. After writing the above I found Colonel Whittlesey had noted these pulsations, and he speaks of them as follows:

"There is a sudden flux and reflux, which is completed in a few seconds, or minutes; sometimes due to storms, but more often cannot be traced to any cause. These oscillations are not yet explained, they occur on all the lakes and upon other bodies of water, causing a rush into the mouths of rivers, generally of a few inches in height, but sometimes of several feet."

Upon further search I find that this same phenomenon has been noticed on the lake of Geneva and the Baltic, under the term "Seiches," and Schulten has demonstrated the direct connection between the "Seiches" of the Baltic and the height of the barometrical column.

"When pressure of air diminishes, the water begins to swell (Seichie). When barometer again rises, the surface of the sea sinks; the movements of the water are always a few minutes earlier than those of the instrument on account of the greater mobility of the aqueous particles."

I make the above quotations as apropos and a confirmation of my views. It seems as if careful observations on the great lakes with self registering water barometer and gauge in connection with the meteoro-

logical information obtained by the Weather Bureau could not fail to be productive of results most satisfactory in the development of the law of storms and atmospheric disturbances.

The disturbances of water level in the lake might be classified as follows:

I. "Seiches" or water swelling.
II. Lunar tide.
III. Fluctuation directly due to wind.
IV. Annual fluctuation.
V. Secular "

Of these disturbances, I., III. and IV. are important factors as affecting the regimen of lake tributaries at their mouths.

Ice Gorge at the Mouth of the Cuyahoga.—In the spring of 1881, the ice gorged at the mouth of the Cuyahoga, flooding the docks in some places and causing great apprehension. The action of the gorge affords an interesting study, and I have shown the effect on Pl. 1. Before its formation, the water possessed an average depth of 17 feet at the ends of the piers. The dotted contours show the 15, 16 and 17 feet curves in June, 1880, the full contours the same in April, 1881. The latter represent more nearly the normal condition of the shoal, and in all probability, with slight modifications, represented the state of affairs at the time of gorging. The retreating footsteps of the gorge, are shown by the erosions at *A*, *B*, *C* and *D*, the two former being quite deep, a scour of 5 feet in some places.

After leaving the points *A* and *B*, the flow of the river is again checked at the end of the piers. The river in obedience to its laws attempts to sweep to the eastward over its accustomed course, as is shown by the concavity of the contours at *C*; but in this direction it must of necessity pass over its shoal, which, serving as a nucleus for the collection of ice, offers opposition and throws the path of least resistance to the westward. The aqueous wanderer therefore makes another turn and passes out to the westward. The latent force of the accumulated waters is dissipated by the work of cutting out a new channel, which is shown by the dash and dot lines.

Formation of Bars and Beach.—The general tendency of rivers along Erie's southern shore, and entering normal to the coast line or north and south, is to sweep to the eastward in a curve more or less modified by the winds. This is due to the fact that the westerly wind is the prevailing one and to the downward flow of the lake. In the rivers of this class and of the size of the Cuyahoga, Grand, Ashtabula, and others, the greatest shoal will be found in or near the prolongation of the east pier, and at distance dependent, of course, upon the volume and velocity, in figures, from 200 feet to 500 feet from end of pier. The west wind is therefore quite an ally to the engineer and probably a disappointment to dredgemen.

In regard to the making or advancing of shore lines, the sand collects on the windward side of the piers when exposed to the prevailing wind, or when the topography of the coast line destroys the latter to the windward, considering the wind having the greatest scope of sea.

Marshes.—Most of the tributaries of Lake Erie along the southern

shore are marshy at their mouths. While these marshes at first thought seem to be of no earthly use except as active agents in the dissemination of malaria and gratification of sportsmen : yet they play a very important part in the regulation of these streams in time of flood. The marsh is to the river what the governor is to the steam engine. They are the natural storage reservoirs for surplus water. It may be well to note the fact that the amount of evaporation is greatly increased by the spreading of this dangerous excess over the vast area of the swamp land. It is evident that the reclamation of these low lands will have the effect of raising the water level and changing the regimen of the adjacent stream.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

WESTERN SOCIETY OF ENGINEERS.

JULY 18, 1882 :—The 150th regular meeting was held at 4 P. M., Vice-President Cregier in the chair.

The Secretary stated that at the meeting June 20 no quorum was present, and no business was transacted, and that on Tuesday, July 4, no meeting was held.

Application to be admitted as a Member was presented from Charles S. Pease, U. S. Civil Assistant Engineer, Council Bluffs, Ia., indorsed by Messrs. Bradley, Cooley and Seeley.

Mr. Benezette Williams, for the Committee on Diploma, submitted the following form, which was adopted :

The Western Society of Engineers.

Organized, A. D., 1869; incorporated under the laws of the State of Il' nois, A. D., 1880.

These are to certify that ...., whose signature appears in the margin, is a Member, or an Associate Member, of the Western Society of Engineers.

Witness our hands and the seal of the Society at Chicago, this ...... day of ...., A. D., 18.....

(Signature) ....

[SEAL.]

.... President.

.... Secretary.

Mr. Benezette Williams, Manager in the Association of Engineering Societies reported upon the financial condition of the Association, and stated that an esti mate of the yearly cost of the JOURNAL, based upon the cost to date, will make it four dollars for each copy taken by the societies. An assessment had been made by the Board of Managers upon the societies, and the amount now due by this society was $176.

Upon motion of General Sooy Smith, it was voted that this amount, $176, be paid to the Association.

The Secretary read a letter from Mr. R. Frank Hartford, suggesting that steps be taken to make the Society of more value than at present to non-resident members.

Upon a discussion of the communication, it was voted that a committee, composed of the Chairman and two others, be appointed to report at the next meeting upon the propriety of printing the proceedings immediately after each meeting. The chair appointed Messrs. B. Williams and Liljencrantz as members of this committee.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

MAY 9, 1882:—Regular meeting held ; President J. M. Wilson in the chair. Minutes of the last meeting read and approved. The names of Edwin H. Martin and Edward H. Jones were presented for active membership and were referred to the Membersi ip Committee.

The Committee on Membership reported favorably upon the names of Clarence

O. Arey, Wm. M. Barr, F. H. Strieby and J. E. Smith, who were then elected Active Members of the club.

Mr. Edward Colgrove and Rev. J. W. Brown presented requests for withdrawal from the club, the latter gentleman having removed from the city. The Membership Committee having reported favorably, the requests were granted.

Mr. Morse presented a communication from Mr. A. Gotlieb, President of the Engineers' Society of Western Pennsylvania, stating that their society contemplated an excursion to Kelley's Island for a couple of days in June, and expressed the wish that the Cleveland club might join them. On motion the matter was referred to a committee consisting of B. F. Morse, A. Mordecai and J. S. Oviatt.

Owing to the illness of Mr. Charles Latimer he was not able to present his paper on "Magnetic Geology," as announced.

Mr. G. A. Hyde read a short paper on the origin of "Atmospheric Cold Waves."

N. B. Wood gave an instructive talk on the microscope and its uses, illustrating the same with instruments.

On motion the club adjourned to meet on the second Tuesday evening in June.

M. W. KINGSLEY, Rec. Secretary.

1

Cross Sections of

The Missouri River at Bismarck, Dakota

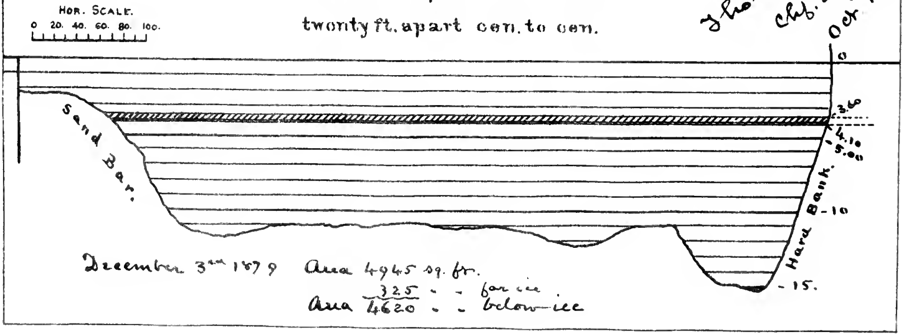
taken to show the influence which the driving of Piles

for a bridge has upon the banks & bottom.

Piers of three piles each driven

twenty ft. apart cen. to cen.

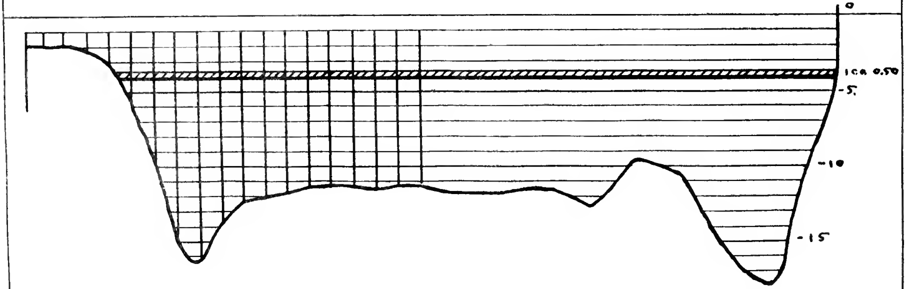
Thomas Doane
Chf. Engr.
Oct 1881.



2

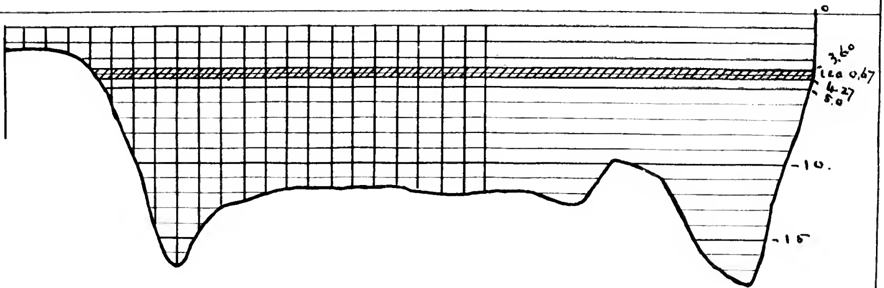
December 6 1879 Area below ice. 5014 sq. ft.

109 lineal feet of piles, or piers of 3 piles, between ice & bottom.



3

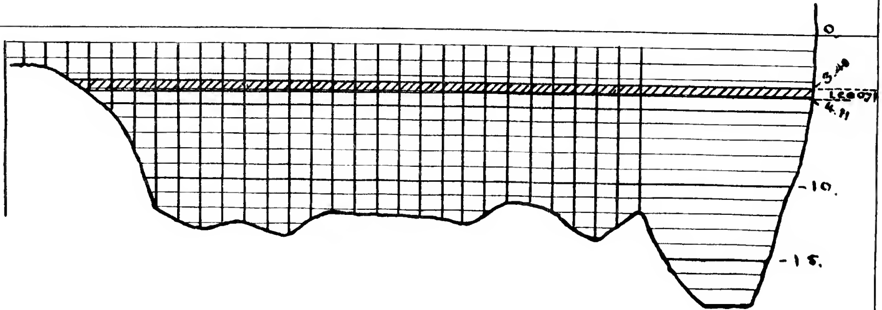
December 8th 1879 evening. Area below ice. 5121. sq. feet
140 lineal feet of piles between ice and bottom



December 9th 1879 Area below ice 5610. sq. feet

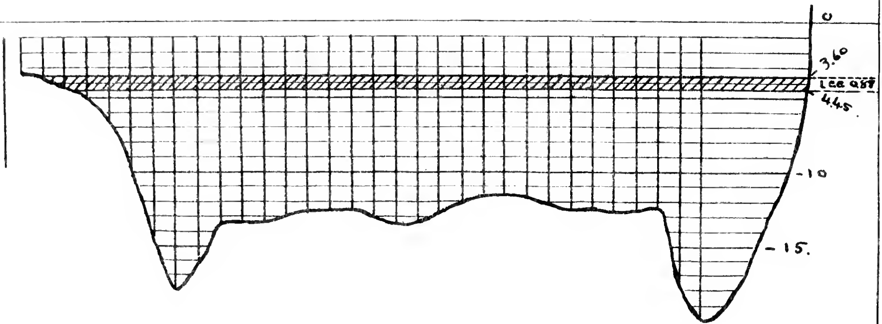
The large increase in area probably due in part to pushing ice beneath.

203 lineal feet of piles between ice and bottom.



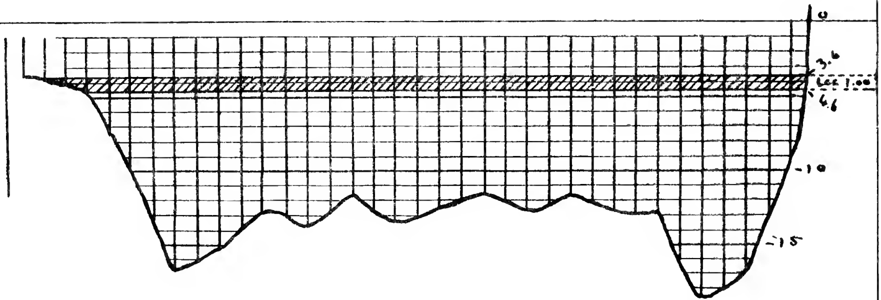
5

December 11th 1879 area below ice 5534 sq. feet.
243 lineal feet of piles between ice & bottom



6

December 13th 1879 Area below ice 5537. sq. feet.
284 lineal feet of piles between bottom of ice & ground
Bridge completed

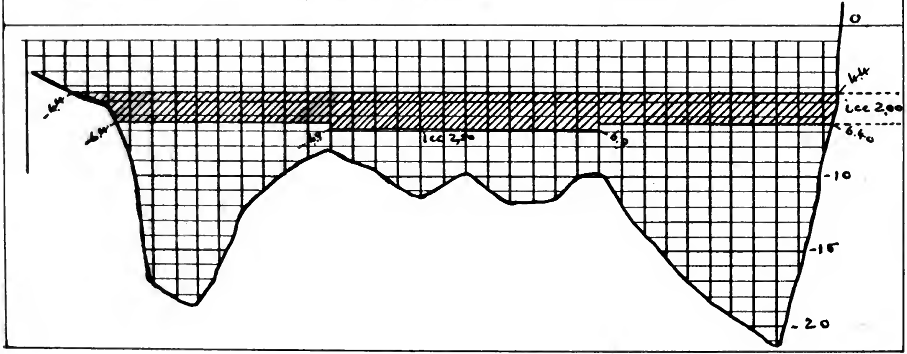


7

January 14th 1880 Area below ice 4161 sq. feet.

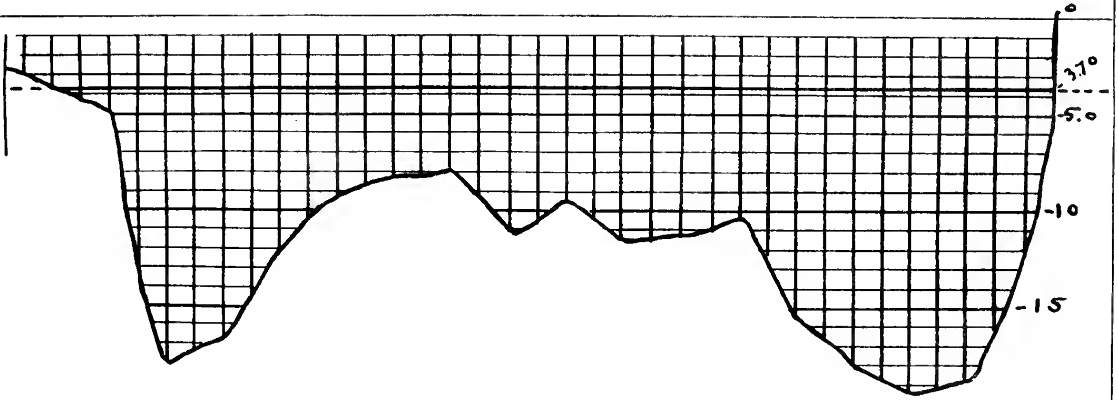
Since the bridge was completed, Dec. 13th 1879. the volume of the river has decreased very much, as indicated by area & elevation of ice.

A marked change in form of bottom due largely to the ice reaching near bottom, at centre.



8

January 21st 1880.



ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. I. AUGUST, 1882. No. 10.

This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

INFLUENCE OF THE PILES OF BRIDGES UPON THE BED AND BANKS OF RIVERS.

By Thomas Doane, Member of the Boston Society of Civil Engineers.

[Read November 16, 1881.]

The observations recorded below were made on the occasion of building a bridge across the Missouri River, at Bismarck, Dakota Territory, for winter use by the Northern Pacific Railroad.

As soon as the ice formed in the river sufficient to lay up the transfer boat, and bear the weight of men, the work of bridging the main channel was commenced. A bridge some 2,000 feet long, across sand bars and shoal sloughs, had previously been built. That across the main channel, which was about 720 feet wide, was begun December 3 and finished December 13, 1879. The line of the bridge made an angle with the river of about 55°. The main channel bridge was built on white oak piles, straight and good, and about 36 feet long, while that across the sand-bar was on cotton-wood piles. The pile-driver was of the kind in which the fall rope did not let go of the hammer, and had two capstan-heads worked by steam. The first-named feature made it possible to strike very frequent blows, and the latter were very useful in hauling the scow on which the driver was mounted among the cakes of ice.

The spans of the bridge on the sand bars were of 15 feet, while those in the main channel were made 20 feet, in order to obstruct the river as little as possible.

Each pier was made up of 3 piles only, standing 5 feet apart centre to centre, and in the river they were so driven as to stand nearly in line with the river current.

Anticipating a change in the banks and bottom by reason of putting in so many piles, the use of oak and long piles was begun some distance away from the river's edge, and they were driven as deep as they would go. They seemed in most cases to reach hard bottom, either of indurated clay or a vein of lignite. The ice was cut away in advance of the scow

with axes and saws, and usually pushed beneath. As the work progressed new ice formed about the piles driven, and furnished all the necessary staging for putting on the top work. This consisted of cottonwood half-squared sticks 12-inch rise and 12-inch faces for caps, and three similar sticks 16-inch rise and 12-inch faces to each bay for stringers. The caps were 12 feet long, the stringers 22 feet. The stringers, instead of butting on the caps, lapped by each other. One was laid nearly over the centre pile, the other two about midway between the centre and exterior piles. Upon the stringers the common cross ties of the track were laid. The ice was about six inches thick when the bridge across the channel was begun, and 12 inches when it was finished. Two or three of the piles were undermined during the winter, and had to be replaced. When the ice went out in the spring, the track only was removed, all of the rest being carried away, the piles also being taken out clean.

The advantages of such a bridge over an ice bridge are that its first cost was not largely greater; that ice sufficient for a bridge may even not be frozen, during any given winter; that its connection with the banks is permanent, and not affected by the rise and fall of the river, and because such a bridge may be built and put to use long before the ice alone is sufficient, and used much after the ice may have become insecure in the spring.

There are furnished herewith cross sections of the river, showing changes in river bed and banks, and progress of pile driving. They are made upon the same scale, so that any one can be laid over any other to compare by inspection the changes. They are of dates December 3, 6, 8 evening, 9, 11 and 13, 1879, and January 14 and 21, 1880, and are numbered in the above order from 1 to 8.*

It will be observed that there is a good degree of uniformity in the latter column of the table. The material of the bed of the Missouri River is very sensitive to an increase of velocity. The three piles in each pier were, of course, *not* exactly in same current line, but the piles were not quite 12 inches in diameter all the way to the bottom, and it may be presumed that the three piles together took up at least a vertical section of the river not less than 12 inches wide. The three piles would also obstruct the river to a greater extent, even if exactly in current line, than one of the same iron cross section.

The table shows that each lineal foot of piles (taking the three as one), caused an increase in river cross section of from 3.2 to 4.8 square feet.

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* Other cross sections were taken December 8 morning, 20 and 26, 1879, and January 16, 17 to 19 and 20, 1880, but they are not here reproduced, as they indicate only slighter changes.

Date.		Total area of water way, in square feet.	Difference between areas on each date and of December 3, in square feet.	Lineal feet of piles counting each pier of three piles as one pile.	Increase of area of water-way in each case, per lineal ft. of pile, in sq. feet.
December	3	4,620	....	....	...
"	6	5,014	394	109	3.6
"	8, morn.	5,162	542	124	4 4
"	8, eve	5,121	501	140	3.6
"	9	5,610	990	203	4.8
"	11	5,534	914	243	3.7
"	13	5,537	917	284	3.2

The volume of the river did not materially change during the ten days of construction. If *any* occurred it must have been somewhat lessened. When a river course begins to freeze up, the water sensibly decreases for a while, the previous supplies being taken up by ice formation, the fall of moisture is in the form of snow rather than rain, and a shrink takes place.

When the work of this bridge was begun the ice was 6 inches thick, and the first great shrink had taken place. During its construction the ice was increased to 12 inches, and the shrink must therefore have been going forward to some extent.

I conclude, therefore, that each foot of pier driven demanded an increase of river area of about 4 square feet.

EXPERIMENTAL STUDY COMPARING THE INFLUENCE OF EXPANSION IN SIMPLE AND COMPOUND ENGINES.

By M. HALLAUER. Read before the Industrial Society of Mulhouse, December 30 1878.

(Translated from *Bulletin of the Industrial Society of Mulhouse*, for May—June, 1879, by CHAS. A. SMITH, Member of tne Engineers' Club of St. Louis.)

FOURTH PAPER.

This analysis of experiments with the Woolf engine is continued from the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, Vol. I., No. 9.

MALMERSPACH ENGINE—EXPERIMENT C, 215 H. P.: EXPANSION, 13.

Account of heat, etc., per stroke :

Weight of fluid in small cylinder	0.5642 k
" " dry steam at cut-off	0.4303 k
" " water " " (23.7 per cent.)	0.1339 k
" " " carried over	0.0304 k
" " " condensed at cut-off	0.1035 k
Heat given to iron	51.34 c
Weight of fluid in large cylinder	0.5642 k
" " dry steam at end of stroke	0.4632 k
" " water " " (17.9 per cent.)	0.1010 k
Internal heat at end of admission, U_0	283.55 c
" " " " stroke, U_1	282.31 c
$U_0—U_1$	1.24 c
Heat furnished by jackets	22.25 c
" " " iron	51.34 c
Total heat furnished during expansion	47.83 c
Heat in total work done	38.79 c
" " external radiation	4.60 c

$Rc = 32.44$ c, being $\frac{31.44}{376.42} = 8.3$ per cent. of the entire heat furnished.

The check on R_c is not as exact as before; but, as we remember that in this experiment the error was 5 per cent., while in the others it was about 2.5 per cent., this is not surprising.

Internal heat at end of stroke, U_0	283.31	c
Back pressure work	8.48	c
Heat retained in condensed water	—13.09	c
	277.70	c
" gained by injection water	295.39	c
R_c	17.69	c

The other method gave 31.44 : $\frac{31.44 - 17.69}{376.42} = 3.7$ per cent. error.

The other experiments were much closer.

The cut-off in the small cylinder being much earlier, it is desirable to calculate the internal heat U_2 at the end of the stroke in the small cylinder.

Weight of fluid in small cylinder	0.5642	k
" " dry steam at end of its stroke	0.4901	k
Internal heat " " " " "	$U_2 = 305.84$	c

MALMERSPACH ENGINE—EXPERIMENT. D., 213 H. P.: EXPANSION, 13.

Account of heat, etc., per stroke:

Weight of fluid in small cylinder	0.5753	k
" " dry steam at cut-off	0.4328	k
" " water " " (24.7 per cent.)	0.1425	k
" " " carried over	0.0310	k
" " " condensed at cut-off	0.1115	k
Heat given to iron	55.31	c
Weight of fluid in large cylinder	0.5753	k
" " dry steam at end of stroke	0.4623	k
" " water " " " " (19.5 per cent.)	0.1121	k
Internal heat at cut-off, U_0	286.44	c
" " " end of stroke, U_1	283.20	c
U_0—U_1	3.24	c
Heat furnished by jacket	22.89	c
" " " iron	55.31	c
" " during expansion	81.44	c
" taken by total work of expansion	39.04	c
" " " external radiation	4.06	c
R_c	37.80	c

Per cent. of entire heat $\frac{37.80}{384.00} = 9.9$ per cent.

The check on R_c:

Internal heat at end of stroke, U_1	= 283.20	c
Back pressure work	7.97	c
Heat retained after condensation	— 15.54	c
	275.63	c
" gained by injection water	307.38	c
R_c	31.75	c

Error, $\frac{37.80 - 31.75}{384.03} = 1.6$ per cent.

At the end of stroke in small cylinder U_2 :

Weight of fluid	0.5753 k
" " dry steam	0.4928 k
" " water 1.43 per cent	0.0825 k
Internal heat at end of stroke in small cylinder	308.79 c

These two experiments with the same expansion, 13. are made, one on the right engine, the other on the left, and give results little different.

The cost per total H. P. of c. is only $\frac{6.983 - 6.878}{6.983} = 1.5$ per cent. better than D.

The proportions of water for C and D respectively are at cut-off, 23.7 per cent.; and 24.7 per cent.; at the end of the stroke in small cylinder, 13.1 and 14.3 per cent., and at the end of stroke in large cylinder, 17.9 and 17.5 per cent., following nearly the $1\frac{1}{2}$ per cent. difference.

R_c differs 8.3 and 9.9 per cent., only 1.6 per cent.

We will take for comparison experiments B, expansion 6: C. expansion 13, and E, expansion 28, all made on the left-hand engine.

The last two experiments throw light upon a fact which should, above all, attract our attention. It is the great evaporation which takes place in the small cylinder during the first expansion. The introduction at full pressure has been carried to nearly half the stroke of the small cylinder, without preventing the evaporation of 10 per cent. of the fluid originally condensed, and a rapid augmentation of the internal heat of the steam, 22.29 c for C, and 22.35 D. (U_0—U_1). We see also that during expansion in the large cylinder a portion of the vapor, existing at the end of the stroke in the small cylinder, has been condensed about 5 per cent., and the internal heat of the steam diminished (U_2—U_1) 23.53 c C, and 25.59 c D.

The number of calories returned by the internal heat during the stroke of the large piston is nearly the same as the work of expansion, 25 c in the large cylinder ; we could then conclude that the steam jacket has done nothing in this second expansion, in a word, does not perform its office.

Arriving at this conclusion will be denying one of the elementary principles of physics, for we know that the greater the difference of temperatures the more energetic the transfers of heat. During the stroke of the large piston the temperature of the steam in the jackets is much higher than that of steam in the cylinders, it is then during this period that the transfer of heat should be best made—that the jacket should furnish more : this is really what takes place.

We will show later in treating of expansion how the passage of calories is made, and what is their occupation : we shall see that his phenomenon, which appears at first to be entirely abnormal, explains itself naturally; we shall see it become a very simple consequence of the principle of the transmission of heat which it seems at first to contradict.

Giving then to terminate the series of analyses the two experiments E and F made with expansions 28 and 25. We regret that we cannot join thereto the analytical story of the engine at St. Remy. Its consumption checks within 3 per cent. nearly, and it agrees closely with the Malmers-

pach engine, but its lacks the exact elements necessary in the indicator diagrams.

MALMERSPACH ENGINE EXPERIMENT E, 143 H. P.: EXPANSION, 28.

Account of heat, etc., per stroke:

Weight of fluid in small cylinder	0.3679 k
" dry steam at cut-off	0.2214 k
" water " (40 per cent.)	0.1465 k
" " carried over	0.0200 k
" " condensed	0.1265 k
Heat given to iron	63.08 k
Weight of fluid in large cylinder	0.3679 k
" dry steam at end of stroke	0.3030 k
" water " " (7.6 per cent.)	0.0640 k
Internal heat at end of admission, U_0	157.44 c
" " " stroke, U_1	183.32 c
U_0, U_1	25.88 c
Heat furnished by jacket	16.09 c
" " iron above	63.08 c
Total heat furnished during expansion	53.29 c
Heat in total work " "	29.35 c
" " external radiation	4.6 c
R_e	19.34 c

Relatively to entire heat furnished $\frac{19.34}{246.77} = 7.8$ per cent.

Check on R_e:

Internal heat at end of stroke, U_1	183.32
Back pressure work	6.63
Heat retained in condensed steam	6.99
	182.96
Heat gained by injection water	198.21
R^e	15.25

Differing from the other $\frac{19.34 - 15.25}{246.77} = 1.6$ per cent.

U_2 at end stroke small cylinder:

Weight of fluid	0.3679 k
" " steam end of stroke	0.2976 k
" " water " " (19.1 per cent.)	0.0702 k
Internal heat at " " U_2	186.81 c

MALMERSPACH ENGINE—EXPERIMENT F, 149 H. P.: EXPANSION 25.

Account of heat, etc., per stroke:

Weight of fluid in small cylinder	0.3862 k
" dry steam at cut-off	0.2471 k
" water " " (36.1 per cent.)	0.1391 k
" " carried over	0.0210 k
" " condensed	0.1181 k
Heat given to iron	58.83 c

Weight of fluid in large cylinder	0.3862 k
" dry steam at end of stroke	0.3180 k
" water " " (17.8 per cent.)	0.0682 k

Internal heat at cut-off, U_0	172.10 c
" " " end of stroke, U_1	192.45 c
$U_0 - U_1$	—20.35 c
Heat furnished by jacket	17.38 c
" " iron above	58.83 c
Total heat furnished during expansion	55.86 c
" " " external radiation	4.60 c
" absorbed by total work "	29.93 c
R_c	21.33 c

being $\frac{21.33}{259.53}$ = 8.2 per cent. of entire heat per stroke.

Check on R_c:

Internal heat at end of stroke, U_1	192.45 c
Back pressure work	6.43 c
Heat retained after condensation	— 7.50 c
	191.38 c
" gained by injection water	210.33 c
R_c	18.95 c

Differing $\frac{21.33 - 18.95}{259.53}$ = 0.9 per cent.

Weight of fluid in small cylinder	0.3862 k
" dry steam at end of stroke	0.3147 k
" water (18.6 per cent)	0.0715 k
Internal heat, U_2	197.46 c

These two experiments, E and F, give results which accord perfectly with expansions 28 and 25. We should also note in order the profound modifications to which the steam is submitted when the expansion is changed from 13 to 28. The internal heat which in C diminishes 1.24 c during the expansion, changes to an increase of 25.88 c E, while for D and F there is for one a diminution of 3.24 c, and for the other an accession of 20.35 c between expansions 13 and 25.

APPARATUS FOR PRINTING BY THE BLUE PROCESS.

By Channing Whitaker, Member of the Boston Society of Civil Engineers.

[Read June 21, 1882.]

The Blue Process is well known to the members of the society, and I need not take time to describe it: but with the ordinary Blue Process printing frame the results are sometimes unsatisfactory, and now that the process has come to be so commonly used I have thought that an account of an inexpensive but efficient printing frame would be of interest. The essential parts of the apparatus are its frame, its glass, its pad or cushion, its clamps, and the mechanism by which the surface of the

glass can easily be made to take a position that is square with the direction of the sun's rays.

The Blue Process Printing Frame in Common Use—Its Defects.—The pad of the apparatus in common use consists of several thicknesses of blanketing stretched upon a back-board. The sensitized paper and the negative are placed between the pad and the plate glass, and the whole is squeezed together by pressure applied at the periphery of the glass and of the back-board. Both the glass and the back-board spring under the pressure, and it results that the sensitized paper is not so severely pressed against the negative near the centre of the glass as it is near the edges. If at any point the sensitized paper is not pressed hard up against the negative a blueish tinge will appear where a white line or surface was expected. With an efficient printing frame and suitable negatives, these blue lines will never appear, and it was to prevent the production of defective work that I undertook to improve the pad of the printing frame.

The Printing Frame Used in Ordinary Photography.—Very naturally, I first examined the printing frame used in ordinary photography. This frame is extremely simple and is very well adapted to its use. It is, undoubtedly, the best frame for blue process printing, when the area of the glass is not too large. The glass is set in an ordinary wooden frame, while the back-board is stiff and divided into two parts. A flat, bow-shaped spring is attached by a pivot to the centre of each half of the back-board. The two halves of the back-board are hinged together by ordinary butts. Four lugs are fastened to the back of the frame, and, when the back-board is placed in position, the springs may be swung around, parallel to the line of the hinges, and pressed under the lugs, so that the back of the back-board is pressed most severely at the centre of each half, while the glass is prevented from springing away from the back-board by the resistance of the frame at its edges. Unless the frame is remarkably stiff, it will resist the springing of the glass more perfectly in the neighborhood of the lugs than elsewhere. It will now be seen, that, on account of the manner in which the pressure is applied, the back-board tends to become convex toward the glass, while the adjacent surface of the glass tends to become concave toward the back-board, and that with such a frame, the pressure upon all parts of the sensitized paper is more nearly uniform than when the pressure is applied in the manner before described. With a small frame of this description, a piece of ordinary cotton flannel is used between the back-board and the sensitized paper, and, with larger sizes, one or more thicknesses of elastic woolen blanket are substituted for the cotton flannel. There is an advantage in having a hinged back-board like that which has been described, because, when the operator thinks that the exposure to sunlight has been sufficiently prolonged, he can turn down either half of the back and examine the sensitized paper, to see if the process has been carried far enough. If it has not, the back-board can be replaced, and the exposure continued, without any displacement of the sensitized paper with respect to the negative. This is an important advantage.

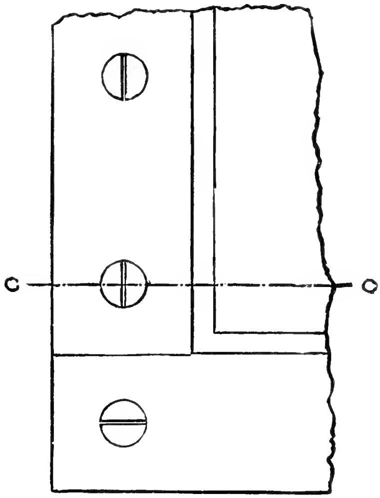
An Efficient Blue Process Frame, for Printing from Large Negatives, or

for Printing Simultaneously from many Small Ones.—In order to be efficient such a frame must be capable of keeping the sensitized paper *everywhere tightly pressed against the negative.* Again, such a frame being large is necessarily somewhat heavy. It should be so mounted that it can be handled with ease, and, in order that it may print quickly, it should be so arranged that it can be turned without delay, at any time, into a position that is square with the direction of the sun's rays.

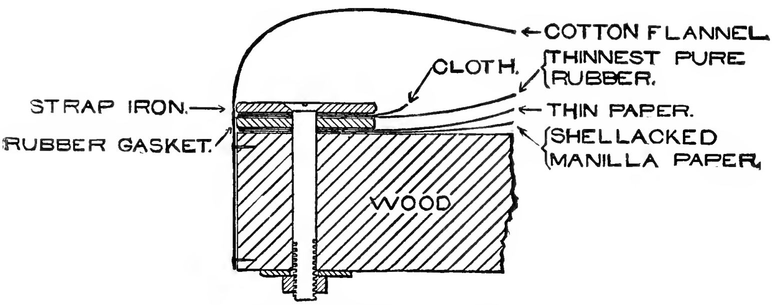
Undoubtedly, if a sufficiently thick plate of glass should be used, the ordinary photographic printing frames would answer the purpose, whatever the size, but very thick plate glass is both heavy and expensive. Commercial plate glass varies in thickness from one-fourth to three-eighths of an inch, and the thicker plates are rather rare. A large plate of it is easily broken by a slight uniformly distributed pressure. But the pressure that is required for the blue process printing, although slight, is much greater than is used in the ordinary photographic process. For, the sensitized paper that is used in the blue process printing is, comparatively, very thick and stiff, and it may cockle more or less, while the paper that is used in ordinary photography is thin and does not cockle. Now, it is easy to see that a pressure severe enough to flatten all cockles must be had at every part of the sensitized paper, and, that if the comparatively thin, inexpensive, light weight, commercial plate glass is to be used, it is desirable to have the pressure *nowhere much greater than is needed for that purpose*, lest the fragile glass should be fractured by it. In each of my large frames : I use the commercial plate glass : instead of the cushion of cotton flannel, or of flannel, I use a cushion filled with air of sufficiently high pressure to flatten all cockles, and to press all parts of the sensitized paper closely against the negative : and instead of the hinged back-board I use a back-board made in one piece and clamped to the frame of the glass at its edges. Connected with the cushion, is a pressure gauge, and a tube with a cock, for charging the cushion with air from the lungs. Experience shows what pressure is necessary with any given paper, and the gauge enables one to know that the pressure is neither deficient nor in excess of that which is safe for the glass.

The Construction of the Air Cushion.—The expense of such an air cushion seemed at first likely to prevent its being used: but a method of construction suggested itself, the expense of which proved to be very slight. The wooden back-board, as constructed, is made in one piece containing no wide cracks. It has laid upon it some thick brown Manila paper, the upper surface of which has been previously shellacked to make it entirely air-tight. Upon this shellacked surface is laid a single thickness of thin paper of any kind, even newspaper will answer. Its object is simply to prevent the sheet rubber, which forms the top of the air-cushion, from sticking to the shellacked paper. The heat of the sun is often sufficient to bring the shellac to a sticky state. It would probably answer as well to shellac the under side of the paper, and to use but one sheet, but I have not tried this plan. Around the periphery of the pad, there is laid a piece of rubber gasket about one and a half inches wide, and about one-eighth of an inch thick. In order that the gasket may not be too expensive, it is cut from two strips about three inches

wide. One of them is as long as the outside length of the frame, and the other is as long as the outside width of the frame. Each of these strips is cut into two L-shaped pieces, an inch and a half in width, with the shorter leg of each L three inches long. When the four



PLAN.
COTTON FLANNEL REMOVED.



SECTION AT CC.

pieces are put together a scarf joint is made near each corner, having an inch and one-half lap. It is somewhat difficult to cut such a scarf joint as perfectly as one would wish, and it is best to use rubber cement at the joints. Over the gasket is laid a sheet of the thinnest grade of what is called pure rubber or elastic gum. Above this, and over the gasket, is placed a single thickness of cotton cloth, of the same dimensions

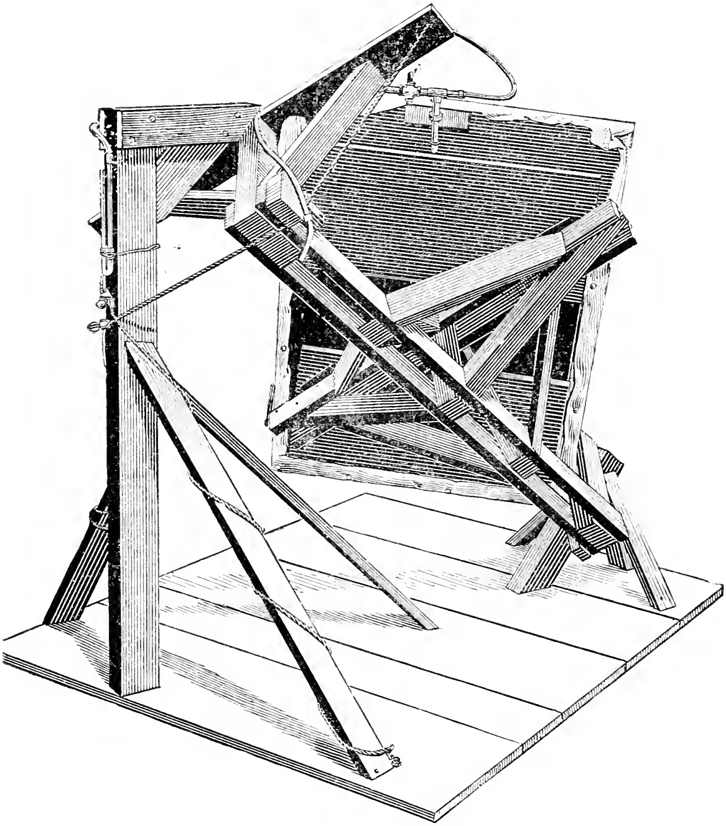
as the gasket, and yet above this are strips of ordinary strap iron, an inch and a half wide and nearly one-eighth of an inch thick. These strips are filed square at the ends and butt against each other at right angles. As the edges of the strips are slightly rounded they are filed away sufficiently to form good joints wherever the others butt against them. The whole combination is bound together by ordinary stove bolts, one-quarter of an inch in diameter, placed near the centre of the width of the iron strips, and at a distance apart of about two and one-half inches. Their heads are countersunk into the strap iron. In making the holes for the stove bolts through the thin rubber, care should be taken to make them sufficiently large to enable the bolt to pass through without touching the rubber, otherwise the rubber may cling to the bolts, and if they are turned in their holes the rubber may be torn near the bolts and made to leak. A rough washer, under each nut, prevents it from cutting into the back-board. For the purpose of introducing air to, or removing air from, the pad, a $\frac{3}{8}$ inch lock nut nipple is introduced through the back-board, the shellacked paper, and its thin paper covering. Without the back-board a T connects with the nipple. One of its branches leads, by a rubber tube, to the pressure-gauge, which is a U tube of glass containing mercury. The other branch has upon it an ordinary plug cock, and, beyond this, a rubber tube terminating in a glass mouth-piece. When it is desired to inflate the air-cushion, it is only necessary to blow into the mouth-piece. A pressure of one inch of mercury is sufficient for any work that I have yet undertaken. With particularly good paper, a lower pressure is sufficient. Upon the top of the pad is laid a piece of common cotton flannel with the nap outward, and with its edges tacked along the under edge of the back-board. The cotton flannel is not drawn tight across the top of the pad. The reason for employing a cotton flannel covering is this: When the sheet rubber has been exposed for a few days to the strong sunlight it loses its strength and becomes worthless. The cotton flannel is a protection against the destruction of the rubber by the sunlight. I first observed this destruction while experimenting with a cheap and convenient form of gauge. I used, as an inexpensive gauge, an ordinary toy balloon, and I could tell, with sufficient accuracy, how much pressure I had applied, by the swelling of the balloon. This balloon ruptured from some unknown cause, and I made a substitute for it, out of a round sheet of thin flat rubber, gathered all around the circumference. I made holes about $\frac{1}{4}$ of an inch apart, and passing a string in and out drew it tight upon the outside of a piece of $\frac{3}{8}$ inch pipe. I then wound a string tightly over the rubber, on the pipe, and found the whole to be air tight. This served me for some time, but one day on applying the pressure, I found a hole in the balloon which looked as if it had been cut with a very sharp knife. That it had been so cut, was not to be imagined, and on further examination, I found that the fracture had occurred at a line, which separated a surface in the strong sun-light from a surface in the shade, at a fold in the rubber. I saw that all of the rubber which had been continuously exposed to the intense sun-light, had changed color and had become whiter than before, and that that portion of the balloon had lost its strength. I then returned to the use of the mercury gauge, and took the precaution to

cover my pad with cotton flannel, as a protection from the light and from other sources of destruction. This pad is upon the roof of the Institute and is exposed to all weathers. As a protection from the rain and the snow, the whole is covered again with a rubber blanket. It has withstood the exposure perfectly well, for a year, without injury. The gauge, made from flat rubber is altogether so cheap, and so convenient, that I am now experimenting with one of this description, having a black cloth covering upon the outside. The balloon is of spherical shape, the black cloth covering is of cylindrical shape, and I hope that this device will serve every necessary purpose. A sectional view of the air cushion is offered as a part of this communication.

The Frame, which Contains the Plate Glass, is made of thick board or plank, with the broad side of the board at right angles to the surface of the glass. A rabbett is made for the reception of the glass and four strips of strap iron, overlapping both the glass and the wood, and screwed to the wood, keep the glass in position. Strips of rubber are interposed between the glass and the wood, and between the glass and the iron. The frame is hinged to the back-board by separable hinges, so that the glass can be unhinged from the pad without removing the screws. Hooks, such as are used for foundry flasks, connect the frame with the pad upon the opposite side. A frame made in this manner is very stiff and springs but little, and its depth serves an excellent purpose. The air-cushion and the frame are so mounted that they can be easily turned to make the surface of the glass square with the direction of the sun's rays. It is necessary to have a tell-tale connected with the apparatus, which will show when the surface of the glass has been thus adjusted. The shadow of the deep frame is an inexpensive tell-tale, and enables the operator to know when the adjustment is right. I have now described, in detail, the construction of the air-cushion with its back-board, as well as that of the frame which holds the plate glass, and I think it will be evident that the first cost of the materials of which they are made is comparatively little, and that the workmanship required to produce it is reduced to a minimum. It will also, I think, be evident, that a uniform pressure, of any desired intensity, can be had all over the surface of the sensitized paper for the purpose of securing perfect contact between it and the negative. The blue copies that are taken with this apparatus are entirely free from blue lines when the negatives, chemicals, and paper are good.

The Mechanism for Adjusting the Surface of the Glass, Until it Shall be Perpendicular to the Direction of the Sun's Rays.—I have found many uses for the blue copying process in connection with the work of instruction at the Massachusetts Institute of Technology. Notes printed by it are far better and less costly than those printed by papyrograph. I wil not detain you now with an account of the uses that I have made of it. I will merely say that more than a year ago I found that my frame, which has a glass 3 feet × 4 feet, was wholly inadequate to the work in hand, and I tried to increase the production from it by diminishing the time of printing. The glass of this frame was horizontal, except when one of its ends was tilted off from the slides which guided it when pushed out of the window; and I knew that it took three or four times as long to print when the sun was low as it did when the sun was near the meridian. I

made plans for mounting this frame upon a single axis, about which it could be turned after it had been pushed through the window, but I saw that no movement about a single axis would give a satisfactory adjustment for all times of the year, and I considered what arrangement of two axes would permit a rapid and perfect adjustment, at all times, with the least trouble to the operator. It was evident that when the sun was in the equatorial plane, the surface of the glass should contain a line which



was parallel to the axis of the earth; and further, that if such a glass was firmly attached to an axis which was parallel to that of the earth, it would fulfill the desired purpose. For the glass, being once in adjustment, is only thrown out of position by the rotation of the earth, and if the glass is rotated sufficiently about its own axis, in a direction opposite to that of the earth, it will retain its adjustment. In order to have the adjustment equally good when the sun was either north or south of the equatorial plane, it was sufficient to mount a secondary axis upon the primary one, and at right angles to it. About this the glass could be turned

through an angle of 23½°, either way, from the position which it should have when the sun was in the equatorial plane.

The Construction of the Adjusting Mechanism.—I desired to have the mechanism as compact and inexpensive as possible, and to have the frame well balanced about the primary axis, in every position. I also desired to have a rotation of nearly 180 degrees about the principal axis. The plan adopted will be most easily understood by referring to the drawing which illustrates it. The axes are composed chiefly of wood. They are built up from strips which are 3 inches × ⅞ inches, and from small pieces of 2-inch plank. They are stiffly braced. A pair of ordinary hinges permit the secondary rotation to occur, while a pair of cast-iron dowel pins with their sockets, such as are used in foundry flasks, serve as pivots during the primary rotation.

The Adjustments.—The adjustment about the secondary axis does not need to be made more frequently than once a week, or once a fortnight. In order to prevent rotation about this axis when in adjustment, two cords lead from points which are beneath the back-board, and as far removed from the secondary axis as is convenient. Each cord passes forward and backward through four parallel holes in a wooden block which is attached to the primary axis. The cords can be easily slipped in the holes by pulling their loops, but the friction is so great that they cannot be slipped by pulling at either end. It takes about twice as long to make the adjustment as would be necessary if a more expensive device had been used; but this device is at once so cheap, so secure, and has so seldom to be used, that it was thought to be best adapted for the purpose. To prevent rotation from occurring about the primary axis when it is not desired, a bar parallel to the secondary axis is attached by its middle point to the primary axis near one end. A cord passes from either end of this bar, through cam-shaped clamps, which were originally designed for clamping the cords of curtains with spring fixtures. These clamps are cheap. They are easily and quickly adjusted, and are very secure.

The whole apparatus can be located upon the roof of a building, or, if convenient, it can be mounted upon slides, and pushed through an open window, when it is to be exposed to the light. If it is to be used upon a roof, a small hut, or shelter of some sort, near by is a great convenience to the operator, particularly in the winter.

An Inexpensive Drying Case for use in Coating the Paper.—When the apparatus is in continuous use, time may be saved by having a convenient arrangement for drying the sheets that have been coated with the sensitizing liquid. I have made an inexpensive drying case which serves the purpose very well. It consists simply of a light-tight rectangular case of drawers. There are twenty-five drawers in all. They are constructed in an inexpensive manner, and are the only parts of the case that are worth describing. They are very shallow, being but 1⅞ inches deep and as it appeared that the principle expense would be for the materials of which the bottoms of the drawers should be composed, it was decided to make the bottoms of cotton cloth. This cloth is stretched upon a frame, the dimensions of which are greater than that of the paper to be dried. The stock of which the frame is made is pine, 1¼ inches wide and ⅜ of an

inch thick. The corners are simply mitred together and attached to each other by means of the wire staples that are commonly used for fastening together pages of manuscript, and which are called "novelty staples." Eight staples are used at each mitre, four above and four below the joint. Two of the staples, at the top and near the ends of the joint, are set square across it, and two others, at the top and near the middle of the joint, are placed diagonally across it. The staples at the bottom are similarly placed. The joint is quite firm and strong and is likely to hold for an indefinite period, with fair usage. The cloth, stretched upon the frame, is fastened to it by means of similar staples. A dark colored cloth not transparent to light is to be preferred. A strip of pine, $1\frac{13}{16}$ inches wide and $\frac{3}{8}$ of an inch thick, forms the vertical front of the drawer and prevents the admission of much light from the front while the sheet is drying. Two triangular knee pieces, $\frac{3}{4}$ of an inch thick, serve to connect the front board with the frame, and four small screws with a few brads are used in attaching them. The lower edge of the front board drops $\frac{1}{4}$ of an inch below the bottom of the drawer. My case stands in a poorly lighted room, and paper dried in this case and removed to a portfolio as soon as it is dry, does not seem to be injured by the light that reaches it. With the case in a well lighted room, I should prefer to have outer doors to the case, made of ordinary boards 6 or 8 inches wide, hinged to one end, and arranged to swing horizontally across the front of the case. These would more completely prevent the admission of light. The opening of any one of the doors would allow three or four of the drawers to be filled, while the rest of the case would be comparatively dark at the same time.*

The Portfolio for Protecting the Sensitized Paper from Exposure to Light.—The sensitized paper is very well protected from exposure to light, if kept in a portfolio or book, the brown paper leaves of which are considerably larger than the sensitized sheets. The sheets may be returned to such a book, after exposure, and washed at the convenience of the operator. They can be washed more quickly and perfectly if *two* water-tanks are provided in which to wash them. A few minutes soaking will remove nearly all of the sensitizing preparation which has not been fixed by the exposure. If the soaking is too long continued in water that is much discolored by the sensitizing preparation, the sheets become saturated with the diluted preparation, and they may become slightly colored by *after* exposure. If the first soaking is not too long continued, and if the sheets are transferred at once to a second bath of clean water, which is kept slowly changing from an open faucet, they may remain there until the soluble chemicals have been entirely extracted, and there will be no risk of staining by after exposure. Washing in two tanks is of more consequence when the ground is white and the lines blue, than when the ground is blue and the lines white.

The Grades of Paper that are Well Adapted for Blue Process Work.—I have tested many grades of paper, to ascertain if they were well adapted

* Since this paper was read, I have seen in the office of the City Engineer of Boston a drying case, which is similar in some respects to the one that I have devised. It has been longer in use than my own. The drawers are simply the ordinary mosquito netting frames covered with cotton netting. They have no fronts, but a door covers the front of the case, and shuts out the light.

for blue process work. Some grades of brown manila are very good: others have little specks embedded in their surfaces which refuse to take on a blue tint: still others, when printed upon, have white lines that are wider than the corresponding black lines of the negative. The blue obtained upon bond paper appears to be particularly rich, and the whites remain pure: but bond paper cockles badly, and the cockles remain in the finished print. Weston's linen record is an excellent paper. It is strong, cockles but little, and dries very smooth. A paper that is used by Allen & Rowell, for carbon printing, is comparatively cheap, and an excellent paper. It is not so stiff as the linen record, and the whites are quite as pure. It does not cockle, neither does it curl while being sensitized. It comes in one hundred-pound rolls, and is about 30 inches wide. The best papers are those that are prepared for photographic work. The plain Saxe, and the plain Rives, both give excellent results. Blue lines on a pure white ground can be obtained on these papers, from photographic negatives, without difficulty. None of the hard papers of good grade require the use of gum in the sensitizing liquid. The liquid penetrates the more porous papers too far, when gum is not used, and without it good whites are seldom obtained upon porous paper.

The best Chemicals for this Work are the *recrystallized* red prussiate of potash, and the citrate of iron and ammonia, *which is manufactured by Powers & Wightman*, of Philadelphia. If the red prussiate has not been recrystalized, the whites will be unsatisfactory, and the samples of citrates of iron and ammonia which have come to us from other chemists, than those named, have all proved unreliable for this process.

The Sensitizing Liquid-Its Proportions.—The blue process was originally introduced from France, by the late Mr. A. L. Holley. I was indebted to Mr. P. Barnes, who was with Mr. Holley at the time, for an early account of it, and I had the first blue process machine that was in use in New England. Since 1876, instruction in the use of the blue process has been given to the students of mechanical engineering of the Massachusetts Institute of Technology, and they have caused its introduction into many draughting offices. The proportions of the sensitizing liquid, as originally given me by Mr. Barnes were as follows:

Red prussiate of potash	8 parts.
Citrate of iron and ammonia	8 parts.
Gum arabic.	1 part.
Water	80 parts.

Results of Experiments.—In our use, it first appeared that the gum might be omitted from the preparation when sufficiently hard papers were used. Next, that a preparation containing

Red prussiate of potash	2	parts
Citrate of iron and ammonia	3	do
Water	20	do

printed more rapidly. This preparation I continue to use when much time may elapse between sensitizing and printing; but, when the paper is to be printed immediately after sensitizing, I use a larger proportion of citrate of iron and ammonia. Before arriving at the conclusion that these

proportions were the best to be used. I made a series of purely empirical experiments, beginning with the proportions.

Red prussiate of potash	10 parts
Citrate of iron and ammonia	1 part
Water	50 do

and ending with the proportions

Red prussiate of potash	1 part
Citrate of iron and ammonia	10 parts
Water	50 do

I found the best plan for conducting these experiments to be: to coat a sheet of the paper with a given mixture; to cut the sheet into strips before exposure: to expose all the strips of the sheet, at the same time, to the direct sunlight without an intervening negative: and to withdraw them, one after another, at stated intervals. I found that with each mixture there was a time of exposure which would produce the deepest blue, that with over exposure the blue gradually turned to gray, and that if a curve should be plotted, the abscissas of which should represent the time of exposure, and the ordinates of which should represent the intensity of the blue, the curves drawn would have approximately an elliptical form, so that if one knew the exact time of exposure which would give the best result with any mixture, one might deviate, two or three minutes either way, from that time without producing a noticeable result. I have found that, with the same paper, the same blue results with any good proportions of the chemicals named, provided a sufficient weight of both chemicals is applied to the surface; that an excess of the red prussiate of potash renders the preparation less sensitive to light, and very much lengthens the necessary time of exposure: that the prints are finer with some excess of the red prussiate; that an excess of the citrate of iron and ammonia hastens the time of printing materially: that a greater excess of the citrate causes the whites to become badly stained by the iron, while a still greater excess of the citrate, in a concentrated solution, causes the sensitized paper to change without exposure to light, and to produce a redder blue or purple, which does not adhere to the paper, but may be washed off with a sponge. I have found that the cheapest method of reproducing inked drawings that have been made on thick paper is not to trace them, but to print the blues from a photographic glass negative; and, also, that the dry-plate process is well adapted to such work in offices, when one has become sufficiently experienced. Printed matter can also, most easily and inexpensively, be reproduced by the same means, when a small issue is required on each successive year. For the reproduction of manuscript by the blue process, the best plan that I have found has been to write the manuscript upon the thinnest blue-tinted French note-paper, with black opaque ink—the stylographic ink is very good—and, afterward, to dip the paper into melted paraffine, and to dry the paper at the melting temperature. This operation, if cheaply done, requires special apparatus. For positive printing from the glass negative, I use a multiple frame, by the aid of which I can print from 16 negatives at the same time, upon a single sheet of paper. This frame is interchangeable with the one that contains the plate glass. The negatives are so arranged in the frame, that the

sheets can be cut and bound, as in the ordinary process of book-binding. The time required for exposure, when printing from glass negatives, varies with the negative, and, in order to secure satisfactory results with the multiple frame, it is necessary to stop the exposure of some, while the exposure of others is continued. I insert wooden or cloth stoppers into the frame, for the purpose of stopping the exposure of certain negatives. When parafined manuscript is to be printed from, I find it convenient to have it written on sheets of small size, and to have these mounted upon an opaque frame of brown Manila paper, printing 16 or more at a time, depending upon the size of the printing frame. Many small tracings may be similarly mounted upon a brown paper multiple frame, and may be printed together upon a single sheet.

UNITED STATES LAKE SURVEY.

By John Eisenmann, Member of the Civil Engineers' Club of Cleveland.

[Read June 13, 1882.]

For fear that your expectations were raised too high by the flattering introduction received at the hands of your estimable president, I beg leave to say that my information, both official and traditional, regarding the U. S. Lake Survey, is limited to but a short decade of its existence, and that information still further limited, in definite knowledge, to a specialty of one of its departments.

Since the final report of this great work will soon be available, I shall limit my remarks to a general review, touching upon its history, its organization, its equipment and its purposes, as they become incidental with the benefits bestowed, the work accomplished, and the acquisitions to science that have resulted from its investigations.

The survey of the north and northwestern lakes, or, as it is popularly known, the United States Lake Survey, began its existence, authorized by acts of Congress in 1841, with an appropriation of $15,000. Since that date annual appropriations have been made, $175,000 being the greatest.

The work has been conducted under the War Department, at first under officers detailed from the Corps of Topographical Engineers, and after the consolidation of that corps with the Corps of Engineers, by officers detailed from the Corps of Engineers, one of whom has always been in charge.

In the beginning the work was entirely done by engineer officers, but as other duties and works assigned to the corps limited the number detailed to five or six, civil assistants were also appointed to act as chiefs of parties. At one time five engineer officers and fifteen civil assistants were on duty as chiefs of parties.

The purpose of this organization, as the name implies, was for obtaining a complete and accurate survey of the United States waters of the great lakes, for the benefit of its commerce.

The earlier surveys were local of some harbor or river in the lower lakes, but when the bordering country became more thickly settled, commerce, growing up with the improvements incidental thereto, de-

manded more extended detailed surveys. Lake Huron was the first of the lakes that had a continuous topographical and hydrographical survey; then followed in succession Lakes Superior, Michigan, Ontario and Erie, together with their connecting rivers and their outlet, the St. Lawrence River.

The charts of the survey were published from time to time, and issued gratuitously to vessels on application of their owners or masters, on filing the requisite affidavits.

The charts are all completed, and complete sets are now available over any route in the lake waters of the United States, extending from Duluth, Minn., to St. Regis, N. Y. That these charts have become invaluable and indispensable to the mariner may be judged from the fact that four or five thousand are issued annually.

The navigator, as he glances over his charts, picking the course through dangerous waters, little thinks, perhaps, of the vast amount of energy labor, thought and money that have been expended to bring them to that state of perfection which makes them so trustworthy as to be indispensable.

To attain this end, the work was based upon one of the best planned, measured and adjusted trigonometrical surveys of modern times, employing for this purpose that branch of civil engineering known as geodetic surveying, the specialties of which were distributed among the following nominally divided departments:

1. Triangulation; 2. Base Lines; 3. Astronomical; 4. Topographical; 5. Hydrographical; 6. Levels of Precision; 7. Meteorological; 8. Comparisons of Standards; 9. Computation; 10. Drafting.

In the Lake Survey report of 1875, we have given the following "normal plan for the survey of one of the great lakes, which was followed as closely as practicable:"

1°. "The establishment of a primary triangulation, the average probable error of whose measured angles shall not exceed four-tenths of a second: the probable error of its bases not exceeding $\frac{1}{300000}$ part of their lengths."

2°. "The determination, from primary triangulation, of secondary points along the shore line to be surveyed, not more than ten or fifteen miles apart, these distances being much less when a secondary or tertiary triangulation can be carried along shore."

3°. "A detailed topographical and hydrographical survey along the shore, based upon these points, extending inland about three-fourths of a mile and lakeward for a half mile, or to the four-fathom curve, scale of topographical sheets $\frac{1}{10000}$ or $\frac{1}{20000}$."

4°. "A belt of off-shore hydrography, done with a steamer, and extending from the four-fathom curve to eight or ten miles from land."

5°. "Lines of steamer soundings across the lake."

6°. "Precise determination of latitude, longitude and azimuths at several primary stations."

7°. "Reduction of field work and construction of maps."

"In some cases, on account of special difficulty or cost, the primary triangulation has not been carried along the lake shore. Thus, on the American side of Lake Huron, points were determined by a combination

of astronomical work and triangulation. On the east and part of the west shore of Lake Michigan, the positions of the points needed for maps were obtained by carrying lines of azimuths and latitudes southward from known points, the longitude being computed from these azimuths and latitudes." * * * * * *

Taking up the work in the order of the departments as classified above, we have first the

TRIANGULATION.

The main system of the primary order extends over the greater portion of Lake Superior, and at Marquette it crosses the Upper Peninsula of Michigan to Escanaba, from which point it spreads over the northern end of Lake Michigan and into Green Bay. From the head of Green Bay it follows up the Fox River to Lake Winnebago, and then, keeping on the Wisconsin divide of the Mississippi and St. Lawrence basins, it extends to Milwaukee and Chicago. At Chicago, one branch reaches south to Parkersburg, Ill., in order to connect with the trans-continental work of the U. S. Coast and Geodetic Survey; the second branch crosses the Lower Lake Peninsula to Lake Erie, and after passing among the islands at its western end, it follows the south shore through northern Ohio to the Pennsylvania boundary, from which point it embraces both shores as far as Buffalo and Niagara Falls.

From Buffalo and the Falls the system continues eastward on the highlands of Northwestern New York as far as the Soduses and Oswego on the south shore of Lake Ontario, from which points the Canadian shore is also included, until the closing line is reached at the head of the St. Lawrence River, near Cape Vincent, N. Y., and Kingston, Ontario. The total length measured along the central axis of the system is over fifteen hundred miles.

A secondary system extends down the St. Lawrence to the iron posts that mark the United States and Canadian boundary at St. Regis, N. Y. A secondary system also extends up the Detroit River into Lake St. Clair and the River St. Clair. This system has as its origin a primary side at the mouth of the Detroit River.

The lengths of the primary triangle sides vary from ten to over one hundred miles. At the apices of these triangles are the geodetic points, generally indicated by metallic marks let into the tops of stone monuments so placed as to preserve them for future reference. The observing stations or scaffolds, from the top of which the instrumental measurements were made, vary in height from twenty to one hundred and twenty-five feet.

The instruments used for reading the angles were specially constructed for the Lake Survey, and are of the most approved of the improved patterns, having every refinement of mechanism and graduation, with the attendant microscopic adjustments which enable observers to take readings to the tenth of a second of arc. The majority of the angles were read with non-repeaters, the mean of sixty-four readings over equally distributed portions of the circle giving the values of the single angles. The three angles of a triangle were measured with a precision whose limit of closure was $180^\circ \pm 3''$.

The secondary triangle sides varied from one mile to ten or twenty in

length; about one-half the number of primary readings were made for each angle, while the limit of closure of a triangle was 180° ± 6″.

Both these systems were checked by carefully measured bases, which is the next topic for consideration.

BASES.

The great system of primary triangulation was checked by base lines of from four to six mile lengths, located at intervals of two or three hundred miles.

The first base is on Minnesota Point, near Duluth, Minn.; the second is on Keweenaw Point, near Portage Lake, an arm of Lake Superior; the third is at Fond du Lac, Wis.; the fourth, at Summit, near Chicago, Ill.; the fifth is at Olney, Ill., a little below the thirty-ninth parallel; the sixth is at Cedar Point, near Sandusky, Ohio; the seventh is on Buffalo Plains, near Buffalo, N. Y.; and the eighth is on the beach of Lake Ontario, near Sandy Creek, Oswego County, N. Y.

The Minnesota base was measured in 1861 with wooden rods, placed end for end on a stretched rope, but as this was rather too primitive to insure the precision demanded by the general character of the other work, it was remeasured in 1870 with the Lake Survey Bache-Würdemann compensating base apparatus. This apparatus is composed of two cylindrical, canvas-covered tin tubes, containing two metallic bars; one of iron, the other of brass, so fixed and adjusted over each other that the unequal expansion of the metals keeps the end surfaces of two agate points at a constant distance during any change of temperature. The tubes, in measuring, are mounted on trestles with adjustable heads for bringing the tubes in contact end for end. Those who are especially interested will find a full description of this apparatus in the Lake Survey Report of 1868—or an illustration and description of the original from which it is copied, in the Coast Survey Report of 1854.

The Keweenaw base was measured with it in 1867, but owing to the many unfavorable conditions prevalent during that measurement, it was remeasured in 1873.

Of the other bases the following were measured with this apparatus: Fond du Lac, in 1872; Sandy Creek, in 1874, and Buffalo, in 1875.

Experience has shown that good work can be done with it, but not of that high standard of precision which had been obtained with what is known as the Bessel metallic thermometer base apparatus. For this and other reasons, the present superintendent, Gen. C. B. Comstock, obtained in 1876 one of these refined apparatuses from Repsold, the celebrated mathematical instrument maker for the imperial government of Germany.

The tube of this apparatus is of thin cast iron, canvas covered, containing two bars, one of steel the other of zinc. The bars are placed side by side and fixed at their centres, while their ends are permitted to slide by each other on expanding or contracting with the changes of temperature. Any change of length owing to the unequal expansion of the metals is read with a filar micrometer, from the comparative scales engraved near the ends of the bars. These micrometers indicate changes to the $\frac{1}{1000}$ths of a millimetre (about $\frac{1}{10000}$ths of an inch).

The length of the tube of the Bessel-Repsold apparatus is four metres.

The following of the above bases have been measured with it: Summit in 1877; Sandusky in 1878, and Olney in 1879. A detailed description of the apparatus and methods of measuring bases with this apparatus may be found in the Lake Survey Report for 1877–78.

The bases in secondary work are measured with rods of iron placed end for end, on adjustable trestles. Average length of bases about two miles.

The bases of tertiary work are measured with a metre chain of 20 m. in length.

Before going any further, I would like to say that the *unit of length to which the Survey's work is reduced, is the metre.* Clarke's value being the accepted length which, when reduced to the English or U. S. standard, is 39.370432 inches.

To my own knowledge, it has been in use thirteen years; just when it was introduced on the Lake Survey I am unable to say. Without entering into a discussion of the historical, traditional and Auld Lang Syne merits of the metric or anti-metric question, I would respectfully refer all those interested to the simplicity and uniformity with which the practicable and scientific data of this great work has been and is being compiled. The anti-metric element may, perhaps, find that their worst fears are groundless, or nothing but the prejudices of conservatism—whereas the metric element will find their brightest hopes realized and being made practicable.

Returning now to the topic next in order, we come to the

ASTRONOMICAL WORK.

The Lake Survey observatory is fully equipped to meet the demands which its work required. There are numerous, valuable, carefully rated chronometers; a large sidereal clock, with an electric chronograph attached, which enables observers to record the transits of celestial bodies to within tenths of a second of time. The observing instruments are of the larger, portable field class, and have all the necessary micrometric adjustments, circles, levels, etc., to insure work of a primary order.

This observatory has been telegraphically connected in latitude and longitude work with the principal observatories of the country, the principal cities and towns along the lake border, and in the four lower tiers of counties of Michigan, with several points in nearly every State and Territory lying along and west of the Mississippi River, and with the temporary observatories at each of the primary bases.

Azimuths of the most refined order were made at each of the primary, secondary and tertiary bases. I think that the Lake Survey observers were among the first, if not the first in this country, to attribute certain irregularities of their observations to the erroneous catalogued positions of the circumpolar stars. It was while they were engaged in the discussion of this problem that the corrections were made public by the *Astronomische Nachrichten*, much to the surprise of the astronomical world, which had considered that the old locations of those stars had been established without a doubt.

TOPOGRAPHY AND HYDROGRAPHY.

The detailed topographical survey extends along the United States

watered border of the lakes and its islands: both sides of the Sault Ste. Marie, St. Clair. Detroit. Niagara and St. Lawrence rivers with their islands, and both shores of Lake St. Clair.

The shore line between the secondary points was either chained or measured by tertiary triangulation. The topographical details were filled in with the theodolite and stadia. the plane table being but sparingly used.

The level contours were determined with the vertical circle. and drawn in to represent ten or twenty foot intervals of elevation above the lake. The field work was plotted on small field sheets as soon as observations were taken. They were afterward transferred in ink to large antiquarian sheets in the office.

The following data will give you some idea of the extent and magnitude of the topographic work. The developed shore line. surveyed from Duluth. Minn.. to St. Regis. N. Y.. measures over six thousand miles; and the number of office antiquarian sheets on which the topographical and in-shore hydrographical work is plotted and compiled to scales of $\frac{1}{10000}$ or $\frac{1}{20000}$. is seven hundred and fifty.

The off-shore hydrography done by the three Lake Survey steamers is plotted to a scale of $\frac{1}{60000}$ on eighty-five antiquarian sheets.

LEVELS OF PRECISION.

Trignometrical leveling was carried along the entire chain of the primary triangulation.

The height or elevation of the lakes above the sea was determined by lines of precise spirit levels. in connection with the water levels of the lakes. The first line of precise levels was run in 1875. from a Coast Survey bench-mark. near Albany. N. Y., to Oswego. N. Y. The second line runs from Port Dalhousie. on Lake Ontario. to Port Colborne. on Lake Erie. The third runs from Rockwood. near the mouth of the Detroit River. to Lake Port. on Lake Huron.

The fourth line of levels of precision runs from Escanaba on Lake Michigan to Marquette on Lake Superior.

Permanent bench-marks have been established at the ends and intermediate points along the lines. The instruments used for the first two lines were of Stackpole and Würdemann construction—those used on the last two lines were of the *Kern* pattern—or same as used on the precise levels of Switzerland. A description of the same may be found in the Lake Survey Report of 1877. and instructions for making precise levels with same, in the Lake Survey Report for 1880.

METEOROLOGICAL.

The water levels observed in connection with the precise spirit levels were made by tri-daily gauge readings extending over an interval of two months. the mean level of the lake for this period being thus referred to the permanent precise bench-marks established for that purpose.

Simultaneous observations or tide readings were kept up at Oswego, Charlotte, and Port Dalhousie, Lake Ontario: at Port Colborne. Cleveland. Rockwood, Lake Erie, and an equal number distributed on the other lakes. This portion of the work fell to the meteorological department. The water level observations of this department have been observed almost uninterruptedly for twenty-five years. at Superior City, Wis. (after-

wards transferred to Duluth, Minn.): Marquette, Mich.; Milwaukee, Wis.; Chicago, Ill.; Port Austin, Mich.; Detroit, Mich.; Cleveland, Ohio; Erie, Penn.; Fort Niagara, N. Y.; Charlotte, N. Y., and Sacketts Harbor, N. Y.

Meteorological observations were kept at numerous points along the lakes, until the organization of the Signal Corps, which has since located stations at or near the former points occupied by the Lake Survey. There are but three points left at which Lake Survey meteorological observations were kept up—to within a recent date—viz.: Port Austin, Mich.; Monroe, Mich., and Sacketts Harbor, N. Y.

The magnetic elements of all the principal points along the lakes have been determined with the most refined and delicate magnetometers used for that purpose.

The outflow of the lakes was gauged at points on the Sault Ste. Marie, Detroit, Niagara and St. Lawrence rivers.

The question of tides and irregular oscillations of the lakes has been fully observed and discussed. The result of the investigations shows conclusively that the great lakes may be characterized as "*inland seas*," subject to the same laws and phenomena which influence the larger oceans.

COMPARISONS OF STANDARDS.

We come now to the comparison of standards, a department of special interest to the student and all those engaged in delicate, refined measurements or manipulations, as well as those interested in accurate standards of measure. In connection with the Lake Survey this department becomes the most absorbing topic, since from it are obtained the values upon which the works of all the others are based.

In the basement of the Lake Survey building at Detroit there is fitted up a room known as the comparing-room. Its location and construction is so arranged that the fluctuation of its diurnal temperature does not exceed 3 F., no matter how large the daily change of the external air may be. This room contains the comparing apparatus, with reading micrometric microscopes, thermometers, etc.; it also contains the Lake Survey standards of length—of inches, feet, yards and metres, and the standard mercurial and metallic thermometers.

The numerous mercurial thermometers are the most refined and delicate of their kind, they have been inter-compared with best standards of Europe and the United States.

Some very interesting developments have resulted from the Lake Survey comparison of its thermometers. Of special notice are the sub-permanent changes, extending over months at a time, which set in with the sudden extremes of temperature. The corrections of the mercurial thermometers are so well known that the probable error of a recorded temperature is but 0.05° F.

The first series of the Lake Survey standards of length, a brass bar of fifteen feet and five single yards, was, I think, obtained from the office of weights and measures, but as their values were not authenticated by any available file records, a second series of five single yards was obtained from the same office. They were carefully compared both at Washington and Detroit, with results far from being satisfactory.

In 1874, a new set of standard yards was obtained from the Ord-

nance Department of England. The yards are known as the "Clarke yards A. and B.," their values and lengths having been determined from comparison with the Royal English standards by the distinguished Lieutenant-Colonel A. R. Clarke, the celebrated authority on standards of length. They are the accepted standard yards of the Lake Survey, and since their arrival have been compared with its earlier standards. These comparisons, I think, indirectly led to the subsequent corrections of the "U. S. standard yard," in order to make it conform with the British standard. This correction was made necessary from the fact that Congress in legalizing the metrical system adopted the ratio which exists between the British and French standards of length; thereby assuming that the standards of the United States were the same as those of Great Britain.

With the Repsold base apparatus there was received a normal steel metre and a metallic thermometer one metre in length, composed of a steel and a zinc bar. These metres had been compared with the German Imperial standards, which depend for their values on the Parisian standards.

They were received at the Lake Survey office in 1876, where they have been compared with all the other standards with results that verify the Clarke value of the metre, and adding another proof to the inaccuracy of the former "United States standard," which also claimed the English royal standard as its source. In spite of these positive proofs, quite a little controversy and opposition was encountered before the other departments were prompted to make public the requisite corrections to their previously published reports.

The above is not the only scientific acquisition of national importance which has resulted from the comparisons of the Lake Survey standards. Its experiments have quite recently corrected, if not overthrown, some of the accepted infallible theories regarding the expansion of metals. The discovery of the sub-permanent changes in mercurial thermometers, extending over long intervals of time, led to the question whether similar changes do not also occur in other metals, or, in other words, is a metallic bar always of the same length for the same temperature?

The Lake Survey observations show conclusively that they are not, but that metals have slight variations for the same temperature, and that when two are combined so as to form a metallic thermometer, the recorded temperatures need corrections depending upon the hour of the day.

This important discovery was, I believe, touched upon for the first time by the United States Lake Survey. I am unable to say whether all its experiments on that point have been completed. They will be before the publication of the forthcoming final report, and will be fully discussed therein.

The importance of this subject will be seen when it is known that the base lines of the triangulation depend upon the accuracy and reliability of the standards of length. Each base is composed of many thousand units of a standard; and any error, however slight, of this single unit is reproduced or multiplied, according to the ratio with which it enters into the length of that line.

These bases should be accurate within the limits that give the least probable error to their length, in order to insure the same degree of accuracy of the computed triangle sides depending on them.

COMPUTATION.

In the computing department, the computations, adjustments, reductions and comparisons of the field work and observations are being made in duplicate by the application of the highest degree of mathematical precision. And, when its labor is completed and the comparisons between the astronomical positions of the extreme northern and southern stations and the trignometrical value of the distance between them have been made, the Lake Survey will have one of the most accurately determined arcs of meridian in the world. It reaches from Isle St. Ignace, on the north shore of Lake Superior, to Parkersburg, Ill., or an arc of about ten degrees in length.

The scientific world is looking forward with great expectation toward the completion and publication of the final report, and after it has perused its pages, there will, probably, awaken a reactionary regret that the good work could not have been continued. Its work was comprehensive and progressive, and under the able leadership of Gen. C. B. Comstock, its present superintendent, the Lake Survey developed into a thoroughly organized, well-equipped body of earnest, scientific investigators; each individual became an enthusiast, honestly and conscientiously searching for the truths of the specialties upon which he was engaged The organization had well earned the patronage of our government, but the jealousies from certain scientific quarters, on finding some of the fallacies of their hobbies exposed, brought to bear the legislative influence which limited its days to the compilation of its final report. Its equipment still remains available to the Corps of Engineers at Detroit. Its officers and civil assistants, with the exception of the few retained for the compilation of the report, are scattered upon the engineering works of the nation—from Maine to Oregon and from the Gulf to the Lakes. The truths that it has promulgated cannot be undone. Its spirit of investigation still lives, and is making its influence felt through the national works of the land, chief among which stands the Mississippi River Commission's examinations and surveys.

DRAFTING.

Before closing my remarks, I wish to call your attention to the excellence of the Lake Survey charts, some of which I have brought with me for inspection. The work was done by the most skilled of topographical draftsmen.

They were projected from the trigonometrical points—referred to latitudes and meridian lines—to scales varying from $\frac{1}{5000}$ to $\frac{1}{40000}$, and are accurate far inside the limits of the scale.

The general charts are on scales of $\frac{1}{400000}$; the coast charts on scales from $\frac{1}{80000}$ to $\frac{1}{120000}$; while the harbor and river charts vary from $\frac{1}{5000}$ to $\frac{1}{30000}$.

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STEAM HEATING.

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[Read by title, June, 1882.]

INTRODUCTION.

The subject of Steam Heating will be presented in this paper under the following heads:

A.—The theory of steam heating, the laws of the transmission of heat and the coefficients used in reducing this theory to practice.

B.—A description of the various systems in use in the United States, with a note on the magnitude of the works employed up to 1881.

C.—A detailed description of the apparatus used and the experiments made under the direction of the writer.

D.—The project of heating a cotton mill with steam, and a comparison of the cost when condensing and non-condensing engines are used to drive the mill.

A.—The Theory of Steam Heating.

The transfer of heat takes place by three processes: Radiation, Conduction, Convection.

In heating a room, for example, with an open grate fire, the heat in the room is mostly radiant heat. The heat of the fire is given to the gas and air in the flue and is carried away by convection. With radiation we have little to do, as in all heating apparatus the heat is brought to and delivered from some intervening solid body by fluids and passed through the solid.

The rate of conduction through a plate is expressed by a well-known formula (Rankine's "Steam Engine," p. 260).

$q = \dfrac{T' - T}{\sigma + \sigma' + \rho x}$ where T and T' are the temperatures of the fluids on either side of the plate, σ and σ^1 are the coefficients of conductivity from the fluids to the plate, and x the thickness of the plate, ρ the conductivity of the plate itself.

For British units with x in inches $\rho = 0.0043$ heat units per square foot

per hour for iron plates, a quantity which, with ordinary thicknesses, is so small that it may be neglected for iron plates.

The terms σ and depend entirely upon the nature of the surfaces and upon the rapidity with which the fluids are circulated and the heat brought to and removed from the plate or surfaces in question. What is required for us as engineers is to determine the limits which appear in practice, leaving to the physicist the general investigation of the laws of the subject.

It has been suggested (*v.* Rankine's "Steam Engine," p. 260) that for iron plates $\sigma + \sigma'$ may be put equal $\frac{a}{T' - T}$, and then $q = \frac{(T' - T)^2}{a}$ and $a = \frac{(T' - T)^2}{q}$, and he further states that for air and water in a furnace and boiler "a" is from 160 to 200 for q in British units.

When the fluids are steam and air, we should expect, from the greater mobility of steam than water, a greater rate of conduction, and we are not disappointed.

From many experiments in the open air, the steam condensed per square foot of pipe surface of ¼ inch thick wrought iron is found to be 1⅜ pounds per square foot per hour when $T' = 220°$ F. and $T = 20°$ F.

In British heat units, the heat given up per pound of steam is 969 units but as the water temperature is not given and is usually from 180° F. to 200° F., we shall make no large error by taking in this and in other investigations the heat delivered by condensing 1 pound of steam as 1,000 heat units: we then have

$$a = \frac{(T - T)^2}{q} = \frac{200 \times 200}{1375} = 29 \text{ nearly.}$$

Experiments made by the writer, which will be described hereafter, give values of "a" as great as 100. As such experiments were made under the usual usage, and are more nearly in accordance with practice, the results, moreover, giving for the larger values of "a" a less rapid transmission of heat, they are obviously the safer to follow in designing heating surface. The great difference is to be attributed entirely to difference in the circulation of the air by which the condensation was effected.

By experiments made in the U. S. Navy, see page 63 of Treatise on Boilers, by Engineer-in-Chief Wm. H. Shock, the transfer of heat is stated to be in proportion to the difference in temperature, instead of the square of the difference as taken by the writer.

The experiments there given appear to give the same quantities as those noted above in the open air, but would be reduced to $q = 2.6\,(T' - T)$ by the writer's experiments under the practical conditions commonly found, and this seems to agree more closely with the usual practice in the United States, and we shall therefore use this formula in preference to the other and more scientific one.

The heat required in any given building will depend upon the heat transmitted to the external air around the building and the amount of air carried through the building or the ventilation. The former effect is

measured by the same formula, $q = \dfrac{T'-T}{\sigma + \sigma' + \rho x}$, where of course the constants have different values, and the latter, by the quantity of air used in ventilation and the amount of heat given to the air.

The constants σ, σ' and ρ vary very much with the materials of the walls and roofs, and the kinds of surfaces; but the most important cause of variation is the rapidity with which the heat is removed from the outside by the action of the wind, and the variation found here is so great that the minor changes become less important. The effect of ventilation is easily computed from the weight and specific heat of air when the quantities are known.

The values of ρ and $\sigma + \sigma'$ are given by some writers on heating and ventilation, but our safest course, as engineers, will be to seek the practical limits given by experience, and we find the limits pretty wide.

According to D. K. Clark ("Manual for Mechanical Engineers," p. 488), M. Peclet found that for $T' - T = 36°$ F. that each square foot of wall would transmit 26 British units per hour, and that the glass windows passed heat at the rate of 30 units in place of 26. The same author gives, on the authority of Mr. Hood (*Idem.*, p. 481), the rate of 1.4 units per square foot per hour per degree of F. of $T' - T$ for glass windows, or for $36°$ $q = 50.4$ units, and the further statement that q varies with the square root of the velocity of the wind. From experiments by the author on large buildings, the transmission varied from 0.67 to 1.25 units per square foot per hour per degree F. of $T' - T$ for the whole surface of walls and windows. The larger values were produced by wind action, and are the ones that should be taken in practice. The effects of a liberal ventilation are included in the above results. The experiments will be given later.

Summing up these results we find that the transfer of heat from steam to air may be expressed as $q = a\,(T'-T)$ where T' and T are the temperatures of the steam and air on each side of a thin iron surface, and q is the rate of heat units per unit of surface per hour.

For T' and T in degrees F. and q in British heat units, $a = 2.6$ for 1 square foot per hour.

For T' and T in degrees centigrade and q in calories per square metre per hour, $a = 12.48$.

For the external surface of a building, including walls, windows and roof together, and taking no account of the material for the maximum transfer of heat, $q = c\,(T'-T)$.

For q in British heat units per square foot per hour $c = 1.25$ for F.°

For q in calories per square metre per hour, $c = 6$ for C.°

For the surface of a steam boiler as ordinarily constructed, $q = \dfrac{(T'-T)^2}{a}$

For British heat units and F.° per square foot per hour, $a = 200$.

For French heat units centigrade degrees and meters, per square meter per hour in calories, $a = 23.14$

$$\frac{1}{a} = 0.0432$$

For keeping any building permanently warm we must have a steady

flow of heat from the furnace to the boiler, from the boiler through the heaters to the air in the building and from the walls to the external air. The same number of heat units per hour must be transferred in each case, whence it becomes easily possible to find the heating surface and boiler surface to warm any given building, taking, of course, the most unfavorable cases, and allowing for losses between the boilers and heaters, and for the ventilation.

Another method of expressing the transfer from heaters to building is by the number of units of volume which can be warmed by a unit of heating surface, and this, of course, varies with the proportions of the building and the range of external temperature, but the application must be to buildings of ordinary proportions, and though more commonly used, is really less reliable in its results.

With the practice of the Dubuque Steam Supply Company, at Dubuque, Iowa, we find that with the external air ranging to 0° F. or — 18° C., 1 square foot of heating surface warms a number of cubic feet as follows, in columns 2 and 4.

	When Heaters are in same Rooms.		When Heaters are in Basements and Warm Air.	
	Cubic ft. per sq. ft.	Cubic metre per square metre.	Cubic ft. per sq. foot.	Cubic metre per square metre.
Dwellings	50	15	40	12
Stores, wholesale	125	37	100	30
" retail	100	30	80	24
Banks, Offices, Drug stores	70	21	60	18
Dry goods	80	24	70	21
Hotels, large	125	37	100	30
Churches	200	60	150	45

To reduce these numbers to cubic metres warmed per square metre we multiply by 0.3, obtaining columns 3 and 5.

In the United States the application of steam for heating was begun in 1842, by J. J. Walworth and Joseph Nason, and the first building heated by steam was a cotton mill in Portsmouth, N. H. The exhaust steam from the engine was used very successfully, and from that time to the present there has been a steady increase in the number and magnitude of the works constructed for this purpose. This has been owing to the severity of the climate and the large number of new buildings erected in the rapid growth of the country. The business of the Walworth Manufacturing Company, of Boston, Mass., in constructing steam heating plant is now $1,500,000 per annum, and there is in the United States a business estimated by competent authorities at $6,000,000 per annum, which has for the past 30 years averaged $2,000,000 per year. In other words, there is now invested in the United States about $60,000,000 in steam heating apparatus, so that in this subject there is no lack of precedents for many kinds of apparatus.

There are two classes of plant used, as was indicated by the columns 2 and 4 of the table above.

When the heaters are placed in the rooms to be heated, the heating is said to be direct. When the heaters are used to warm air in separate chambers, which air is then transferred through flues to the rooms to be warmed, the heating is called indirect.

The choice between these systems is to be governed by other conditions. Where the air is not renewed frequently, or where the space to be warmed is large in plan but not in height, the direct system appears preferable; but where large ventilation is required, or the building is lofty, the indirect method offers many advantages. It appears necessary to provide more heating surface by the latter method; but the labor and expense of fittings is often much reduced thereby, while with improved arrangements there is little difference in the surface required. Usually the movement of the air by which the indirect system heats a building is effected by gravity, but in some instances fans have been employed, requiring, of course, power to drive them.

In regard to the different forms of heaters used in the United States there is great variety, from the single line of large pipe and the manifold lines, where the steam flows through several pipes side by side, to the elegantly finished work used in all the large hotels, and the complicated heaters used with the indirect method.

Within the last three years preceding 1881 steam heating has assumed a new form, by the use of long lines of pipes underground, thus placing the subject upon the basis of a gas or water supply. Companies for this purpose have been formed and works put in operation in many places in the United States. The following table gives some information concerning these works. This list is being rapidly extended, and after passing its experimental stage the subject can be placed upon a good financial basis. At the present time, although the matter is a success from the physical standpoint, yet rates and charges are still in an unsettled condition, and the owners by no means satisfied in most of these places.

City and State.	Pipe Underground.	Remarks.
Lockport, New York	3 miles	
Dubuque, Iowa	860 feet 6 inches	Heats 3,500,000 cubic feet space; has 100 consumers.
	1,960 " 5 "	
	3,818 " 4 "	
	4,441 " 3 "	Boiler capacity 25,000 lbs. water per hour, from 40° F., at 280° F. evaporation.
	205 " 2 "	
	2,073 " 1½ "	
	2,508 " 1¼ "	
	643 " 1 "	
Auburn, New York	1 mile	Heats 6,000,000 cub. ft.
Detroit, Michigan	5,000 feet 6 inches	
	2,000 " 8 "	
	5,000 " smaller than 6 in.	
Milwaukee, Wisconsin	585 feet 10 inches	Heats 5,000,000 cubic feet and runs 10 engines.
	2,540 " 8 "	
	5,156 " 6 "	
	875 " 5 "	
	5,195 " 4 "	
	1,300 " 3 "	
	6,900 " smaller pipe.	

From experiments with pipe laid and protected, as such companies protect them, a loss of heat of the pipes is found at 50 British heat units per square foot per hour with steam at 258° F., the ground at say 58°, 0.05 pounds per square foot per hour being the condensed water by weight. Experiments by the writer gave the same value, but in long lines a further loss takes place by leakage and by imperfect traps, a very essential part

of the system. In fact the experience at Dubuque is that about one-half of the steam made is wasted, according to the statement of the superintendent.

Steam for heating is carried at all pressures in the United States, and while, as well known, no economy in fuel can result from the use of high pressures, yet a smaller plant can be made to do the work, and, in fact, the first remedy in cold weather for cold rooms is to raise the steam pressure until the increased energy of transmission of the heaters produces the desired result.

Boilers for steam heating are of all sorts and kinds, and the only point which is vital in designing them is to keep in mind the range of action to which they will be subjected. For the work of a boiler in making steam for heating is more like that of a locomotive boiler than anything else. Every degree change of temperature, and every change in the wind is felt by the men with the shovels, and quickness of steaming and capacity of furnace for burning fuel is essential. Grate surface enough must be provided to do the work in the coldest weather; and this grate will be too large for economic evaporation in milder weather; and while large boiler surface is a good thing it is not judicious to invest in a boiler large enough to work at a high economy of evaporation during a few days only in a year of the hardest work. It is more economical to crowd the boilers at the expense of the fuel at such times, and a boiler must be provided which can be crowded hard.

C.—In the winter of 1878 the writer placed before the directors of Washington University in the City of St. Louis, Missouri, a plan for heating a portion of the buildings belonging to the University by steam, which plan was adopted by them and built.

The central group of buildings consists of the Academy, the Museum of Fine Arts, the Manual Training School, the University, Laboratory, and Gymnasium: the three latter are called collectively the University. To the west is the Mary Institute, with its own boiler, and to the east the Law School: occupying the old building erected for the Mary Institute: the future of this building being uncertain, it has not been connected for steamheating. The Mary Institute heating apparatus is mainly indirect, and consists of heaters hung in the basement in small air chambers connected by flues to the different rooms. The air heated is taken either from the basement or from out-doors as desired. The operation is quite satisfactory: the steam is at present supplied by two boilers in the building, but it is probable that it will be connected to the central group and operated from the main boiler-house in a short time. It has now been in use for four years. The condensed water returns directly to the boilers. The heaters of cast iron are corrugated castings short and placed horizontally.

The Academy and Museum of Fine Arts are heated by fittings put in by the Walworth Manufacturing Company. In the Academy cold air is taken through openings in the walls close to the heaters, and the foul air passes through flues from the rooms to the top of the building and escapes. The steam and return mains are led around the basement, and vertical steam and return pipes rise through the buildings with one heater connected to them on each floor. As little horizontal pipe is used as possible, and that is kept in the basement. The steam pipes rise all the way

and the return pipes fall all the way. The horizontal steam main must be kept dry and the return main full of water in order to prevent what is known as "snapping," a phenomenon sure to attract attention when it does occur, and which is sometimes dangerous to the joints of the pipes.

"Snapping" is caused in this way: when any of the condensed water finds its way into steam that is warmer than itself, it causes a sudden condensation, and the steam closes up so rapidly that a shock and violent sound result. With large pipes and well-defined currents of steam the water condensed remains at the temperature of the steam and is swept along with it. To illustrate more fully, if, in the Academy building, a heater on the upper floor is shut off, steam will condense in the upper portion of the vertical stand-pipe, and there being no current in the upper portion and not much below, the water stands in drops on the iron cooling and accumulating till it falls into the hotter steam below. A sound like the crack of a rifle is the result. The remedy is to open the heater on the summit of this pair of pipes, or to connect the stand-pipes themselves: a better but more expensive way is to put in a pair of vertical pipes for each heater from the mains in the basement, with the valves at the bottom. The greater portion of the University buildings is heated by tubular heaters in the basement, the warm air being led to the various rooms by flues in the walls and moved only by gravity. The old heaters were of cast iron heated by fires made in them, and the new heaters were applied to the same system of flues. The heaters were described in a paper by Mr. Chas. F. White before the club, and printed in the *American Engineer*. Certain rooms in the upper floors are unprovided with wall flues and are warmed by direct heaters; as these heaters are connected to a pair of horizontal pipes of considerable length, the condensed water does not drain properly. The drying tables and sand baths in the chemical and physical laboratories and one small heater is placed in a small room on the first floor of the south wing, and one on the upper or second floor of the Laboratory building. The Gymnasium is to have heaters of the kind in the upper floor, with horizontal mains in the basement. At the west end of the University building, the heating surface is not sufficient to make up the loss from the walls, and the upper floors draw off the heat from the lower rooms. This could be prevented by controlling the area of the flues which carry away the warm air, but will be remedied by placing heaters in the lower room. With the exception of two rooms the heating is ample in the coldest weather.

The Manual Training School is heated in part by direct and in part by indirect radiation. The two lower floors with the four workshops are warmed 4 lines of 2-inch pipe along the foot of the walls under the benches, and the upper or school-room floor by a pair of tubular heaters in the basement, and one room has two lines of pipes on three sides. The steam is taken either from the steam main or from the exhaust steam of the non-condensing engine used for running the tools in the workshops. The air from the heaters in the basement is conveyed to the ,upper floor by metal flues passing through the floors.

The dimensions of the buildings and surfaces met with are given for

the central group in the following table with French and English units :

APPROXIMATE DIMENSIONS OF BUILDINGS IN THE CENTRAL GROUP.

	Academy.	Manual Training School.	Museum of Fine Arts.	Gymnasium.	University.
Volume, c. f.	450,000	225,000	500 000	100,000	750,000
Volume, c. m.	12,600	6,300	14,000	2,800	21,000
External surface in square feet	36,000	20,000	36,000	13,000	80,000
External surface in metres	3,318	2,418	3,348	1,200	7,440
Heating surface in square feet	3,500	1,870	3,300	500	6,000
Heating surface in metres	323	174	307	46	558
Volume c. f. to 1 square foot heating surface	129	120	152	200	125
To 1 square foot of wall	12.8	11.2	13.9	7.7	9.4
Cubic metres to 1 square metre heating surface	30	36	45	60	38
To 1 square metre wall	3.8	3.3	4.2	2.3	2.8
External surface to heating surface	10.3	10.7	10.9	26.	13.3

The boilers are three in number, set independently, two being used at once. They have each 768 square feet of heating surface, and 24 square feet of grate. The stack is 12.25 square feet aperture at the top, and is 105 feet above the grate bars.

All fuel is weighed, and all water, fresh or return, is measured either by metre or weight as desired. The coal used is bituminous, from the neighboring mines in Illinois, and has a chemical composition capable of evaporating 12 units of water by 1 unit of coal by weight, from and at 212° F.: ash, 12 per cent.

Experiments of March, 1880. Fuel and water weighed for one week; one boiler: maximum coal per square feet of grate, 38 pounds; mean evaporation from and at 212° F., 6.49 pounds: priming, 2 per cent.

Experiments of October, 1880. Coal weighed and water by meter (Worthington) for one week: two boilers: mean evaporation for the week, 7.1 pounds.: maximum for 24 hours, 7.9 pounds.

As the meter was a piston meter, the results are not likely to be in excess of the truth on that account. The weight was charged each time full and empty barrel of water and the time noted.

The priming by the method of Hirn. The work done was exceedingly varied in the March experiments; it was found that at that time the work from 6 A. M. to 12 noon was double that done in the other 18 hours.

Experiments upon the transmission of heat have been made upon the Academy and University buildings only, the quantity of water condensed being noted, with the steam pressure, the temperature of the external air, the air in the buildings and of the return water.

With external temperatures from 10° F. to 45° F., and the buildings from 60° F. to 75° F., steam from 260° F. to 280° F., the values already given for "*a*" on p. 371 were found. The duration of the experiments was from three to eight hours, taken during the ordinary operation of the works The return water was usually from 190° F. to 210° F. The experiment for underground condensation was made in the same way, and lasted five hours.*

* In the experiments with the buildings the ample ventilation was not interfered with. The other buildings have just been completed, and the experiments made with them are only preliminary.

The construction of the boilers was shown in the paper by Mr. White above referred to.

There is one element, not yet mentioned, and that is the time in which the buildings must be warmed. In the experience of the writer at the University buildings the Academy can be warmed in cold weather in three hours, and in fact the steam is only supplied for twelve hours out of the twenty-four. The University building with the indirect heaters has to be kept warm all the time, and in cold weather takes ten or twelve hours to get warm throughout. For rapid heating, the direct system with ample surface appears best adapted: but for steady heating, with purity of air, the indirect is to be preferred.

D.—Suppose that it is required to design the heating apparatus for a large building. This will include the boilers, the heaters and their disposition, and the choice of a system direct or indirect, and the use of exhaust steam from an engine.

To fix our ideas let us consider the case to be that of a cotton mill with the following dimensions:

In English measures, 328 feet long 40 wide and 3 stories of 13 feet in height, making 40 feet say as the height, rectangular in plan, having a volume of 524,800 cubic feet and a surface of 42,560 square feet.

In French measures, 100 metres long 12 metres wide and 12 metres high, having a volume of 14,400 cubic metres and a surface of 3,888 square metres.

Such a mill will contain 10,500 spindles, 225 looms and the proper proportions of cards, with the other machinery belonging to the manufacture of cotton.

Let the lowest external temperature be assumed at 5° F. = —15° C., and let the minimum internal temperature be assumed at 59° F. = 15° C., values which would be likely to suit most localities in the U. S., and even if exceeded would not be very often passed. The range of wall transmission will then be from 59° to 5° = 54° F. = 30° C., and the quantity of heat transferred may reach 54×1.25 units per square foot per hour (see page 371) or 30×6.0 calories per square metre per hour—67.5 English or 180 French units.

$67.5 \times 42,560 = 2,872,800$ heat units per hour, or

$180 \times 3,888 = 699,840$ calories per hour.

To decide upon the amount of heating surface the temperature of the steam must be known. The choice of the direct or indirect methods will probably be made from the form of the building, which covers a large area and is not very high, and the magnitude of the rooms, supposed to be not more than two to a floor, as direct surface; and the kind of heaters by economy only, to be pipes laid along the foot of the walls, or rather along the walls near the floors.

The temperature of the steam will much depend upon where it comes from, from a separate boiler or from the exhaust of an engine, and we will examine three cases:

1st. A separate boiler.

2d. A non-condensing engine.

3d. A condensing engine.

With a separate boiler we are not limited as to pressure except by con-

venience, and we will assume 50 lbs. per square inch above the atmosphere, 65 lbs. absolute, or $4\frac{1}{3}$ atmospheres, the temperature of the steam being 297° F., or 148° C. From p. 371, 297° — 59° = 238° F. = $T' - T$ = 148° — 15° = 133° C., $q = \frac{(T' - T)^2}{100}$ = 566.44 heat units per square foot per hour = 1,528 calories per square metre per hour.

The slight difference in these results is due to a neglect of decimals and is of no practical value.

The boiler, to give this amount of heat, will have to evaporate 2,873 pounds of water per hour, or say 3,000 pounds, and will require, at 4 pounds of water evaporated per 1 square foot per hour, an amount of heating surface = 750 square feet. As this is the maximum capacity, we find that 24 square feet of grate, with coal evaporating 6 pounds water per 1 pound coal, burning 500 pounds per hour, or about 22 pounds coal per square foot of grate, is an ample provision. A smaller grate, with careful firing, would give better results for fuel, but would not be as easy to work on cold days.

The cost of such a boiler set in the United States would not be far from $1,300, including everything ready to use, but not counting any outlay for buildings to put it in. The cost of the pipe in place to make 4,460 square feet of surface for 1-inch or 2-inch pipe would be about 40 cents per square foot, or $1,856. Total cost, $1,856 + $1,300 = $3,156, and including contingencies, say $3,200 at 5 francs per dollar, 16,000 francs, of which the boiler cost 6,500 and the pipes 9,100 francs.

Suppose the steam had been at 212° F. or 100° C. 212° — 59° = 153° F., in place of 238° for $T' - T$, but the transmission is now reduced, and the surface must now be increased 1.55 times to 7,192 square feet, say 7,200, or to a cost of 13,950 francs; total, say 31,000 francs. The steam temperature is now at the lowest possible in a non-condensing steam engine: and if such an engine, using 2,800 pounds of steam per hour, be at hand, the only outlay involved is the pipe surface of 14,000 francs, say: but with the more active circulation of the steam there will be found an increase in the radiating effect, which, however, we will not consider here.

We have then a decrease in the cost of the plant of 400 dollars, or 2,000 francs, which is equivalent to say 40 dollars or 200 francs per year interest and repairs, and we should, of course, recommend the use of exhaust steam.

There remains to be considered the use of a condensing engine, with the exhaust steam at say 100° F = 38° C.

It would be possible, by the use of a very large amount of pipe surface and a very carefully arranged drainage, to return to the air pump: but the great cost of pipe surface and the practical troubles of making pipe joints hold in vacuum would cause us to reject this idea as impracticable, and there remains the use of a separate boiler, or the running of our condensing engine as a non-condensing engine during the winter months.

For ordinary condensing engines the increase of fuel would be in proportion to the increase of work on the forward stroke, rendered necessary by the increase of back pressure, and in such cases it would be desirable to use a separate boiler, as the fuel used would be great ; for example, the

engine using 400 I. H. P., with 4 pounds of coal per H. P. per hour, or 1,600 pounds of coal per hour. The increase of fuel may be measured by the increase of forward work, which, of course, depends upon the engine used; but if the forward mean pressure had been 30 pounds and the mean back pressure 3 pounds per square inch when running condensing, the forward pressure will now be raised to 43 pounds, and the back pressure to 16 pounds, the fuel from 1,600 to 2,292 pounds, or say 700 pounds per hour increase, between three and four francs per hour, say 40 francs per day for the maximum work in heating, but this must be kept up for 100 days, or a cost per year of 4000 francs.

When we compare this with our separate boiler we have an excess of 2,000 francs to begin with, but also the cost of the fuel in addition, which cannot be taken less than 1,800 per year, as estimated below, making together, say 2,000 francs, and we should in this case use the separate boiler and engine.

When, however, we have the mill in good order, and have the best engine in use, that of M. Hirn, using superheated steam, we find that the power is not over 250 horse-power and the fuel 2 pounds per hour per I. H. P., or 500 pounds per hour in place of 1,600, the increase $500\frac{13}{30} - 500 = 217$ pounds, which costs about one franc per hour, or say $200 to $230, or 1,000 to 1,200 francs per year, on the above basis of 100 days of 12 hours.

The cost of the fuel alone for the separate boiler on the basis given above of a maximum of 500 pounds, and say an average of 300 pounds coal per hour, would be from 30 to 40 cents, or $1\frac{1}{2}$ to 2 francs, say for the 100 days of 12 hours: $360, or 1,800 francs, as estimated above, which, with the cost of the boiler, would leave us $160, or 800 francs per year in favor of this plan.

We find then that with non-condensing engines and the best class of condensing engines, the use of exhaust steam is desirable, while with ordinary condensing engines a separate boiler is to be preferred.

The pipe surface for 7,200 square feet can be arranged to take the exhaust steam from the engine through an 8-inch or 10-inch exhaust pipe to the top of the building, and to open into 2-inch pipes on each floor, in two directions, uniting in a descending 10-inch pipe carried to a hot water tank, and the exhaust to be either circulated or turned loose into the air without going through the building.

Seventy-two hundred feet would require 14,400 feet of 2-inch pipe and as we can easily place 300 feet in one line and 600 feet in the two lines, we have twenty-four lines, or four lines of 2-inch pipe on each of the two main walls. The end walls and vertical pipes will make up the amount. Twenty-four lines of 2-inch pipe will present the same resistance that one line of 10-inch, and we need fear no great increase of back pressure above that assumed. (Two-inch pipe is 0.05 m. diameter.) The wall pipes should fall uniformly 1 in 200. Each line of pipe should have its own valve connections, and when most of them are closed the steam allowed to flow directly into the air, as well as through the building, to avoid back pressure. One and one-quarter inch pipe is usually preferred to larger sizes, as being easier to bend without fracture.

In the above recommendation of the use of exhaust steam by discarding the condenser of an engine, it is, of course, supposed that both boilers

and engine can do the required work under the new conditions with entire safety and satisfactorily. This can only be ascertained in the particular instance by a careful and complete examination of the conditions under which the engines are now working, and the change should not be made until the result is clearly foreseen, for the example supposed the best state of things, and for all but the best kind of condensing engines and mills in the best order, we shall not find it advantageous to make so novel a departure, and shall use the separate engine and boiler.

To get the pipe surface three lines of 2-inch pipe in each floor may then be employed.

In the United States the cost of a given surface of pipe is about the same for 1-inch and 2-inch pipe, the labor making up the cost to the same amount. With the larger sizes the cost increases, but for the use of exhaust steam the larger pipe is to be preferred, unless more than one line be used at once in the example above.

[NOTE.—The conclusions of the above paper have been borne out by the experience of the winters 1880–81 and 1881–82.—C. A. SMITH.]

COURSE OF STUDY FOR YOUNG ENGINEERS.

BY JOHN D. CREHORE. MEMBER CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read March 12, 1881.]

Mr. President and gentlemen of the Civil Engineers' Club: Invited to address this meeting on the subject of a course of study for young engineers, or something pertaining to the education of young men for the profession, and being admonished that brevity will be an acceptable quality in the performance of each speaker this evening, I do not attempt an exhaustive presentation of the important and interesting topic assigned me, but offer a few suggestions which may be helpful to young men aiming to become engineers in the best sense of the word. I say "best sense of the word," because, unfortunately, the term "engineer" has been applied to two classes of men differing widely in the amount and quality of their attainments. And so it has resulted that the mere name by itself gives no sign of the ability of the man, nor of the class to which he belongs. I do not now speak of the classes known as mechanical, mining, sanitary, hydraulic and civil engineers, but rather of a difference found in each of these classes—a difference like that between what is genuine and what is spurious; a difference resulting from sufficient and well-directed toil, on the one side, and on the other, from insufficient labor badly directed, or from no true labor at all.

Some years ago I saw an advertisement of what was called a school of engineering, in which it was claimed young men could become accomplished engineers with only six months' study! The course of study to be the short road to so desirable an end was merely some good handbook, such as Trautwine's or Haswell's; and what ability a student could acquire in six months, to use that book, was to be his whole outfit for the engineering profession. I have never heard of that institution since; but I think a search throughout the land for its kind of graduates would be successful.

"But," says one of these hand-book engineers, whose mathematica

knowledge is limited to arithmetic, with only the ability to substitute numbers for the literal parts of his algebraic formula, "have I not in this, my universal text-book, the condensed results of all the demonstrations and investigations contained in the larger works, which not only require years of hard study to be spent on themselves, but absolutely refuse to be studied at all without years of preparatory elementary studies?"

Doubtless the answer must be in the affirmative. Doubtless these condensed results form a vast body of knowledge. And knowledge is power, as, I think, some author has remarked. Therefore, must we conclude that these condensed results inevitably confer power upon our hand-book worshiper? Power to do many things in a certain way they surely do confer; but that power which alone is worthy of being so called, that power which masters all it touches, which can adapt old forms to new uses, or create new and better means of reaching old ends, that power comes not but to him who pays the price fixed in the very nature of things. Let us see what that price is.

Far be it from me to condemn the proper and intelligent use of the class of manuals to which I have referred. In themselves they are invaluable, and no engineer can well be without one. Of their abuse I complain; or, rather, of the abuse of the mental powers of him who trusts solely to them, and the end of whose ambition is to apply formulæ he could not correct if misprinted, nor even detect their typographical errors, nor know, in the case of inexact formulæ, whether their degree of approximation be sufficient for the purpose to which he applies them. Nor do I condemn the employment of short and approximate methods of work when the subject matter admits them. It were as useless to insist on the application of the rigorous prismoidal formulæ, with the exactness implied in a long array of decimals, when the known irregularities of the volume to be measured render it only an approximate prismoid, as to claim absolute accuracy for the measured length of a line when there is so much uncertainty about the point of beginning that no two measures could be sure of beginning at the same point.

If we examine the pages of any first-class work on engineering, we shall find them largely devoted to mechanics as applied to structures and machines; and opening a standard treatise on Analytical Mechanics, we find its processes conducted by means of the symbols and methods of pure mathematics applied to the concrete units of force, time, velocity. From which the inevitable deduction is, that the foundation of that knowledge which alone can give the engineer true power, must be laid in mathematics. And I may add that, into the whole *superstructure* of his education and training, must enter "sound and sufficient knowledge of mathematics" which Sir John Herschel truly calls "the great instrument of all exact inquiry, without which no man can ever make such advances in any of the higher departments of science as can entitle him to form an independent opinion on any subject of discussion within their range." And, in much the same strain, Thomas De Quincy, who surely wasted no praises on mere mathematicians as such, in speaking of Leibnitz, says: "I remarked that Leibnitz, however anxious to throw out his mind upon the whole encyclopedia of human research, yet did not

forget to pay the price at which only any right to be thus discursive can be earned. He sacrificed to the austerer muses: knowing that God geometrizes eternally, he rightly supposed that, in the universal temple. Mathesis must furnish the master-key, which would open most shrines."

I need not remind you of the instances in your own experience, when men have expressed decided opinions upon the capability of a given engineering structure, although they had never taken the first step in the only path that could lead to the right of having any opinion on the subject. But when such men, and such only, are entrusted with the designing, constructing, erecting and maintaining of important structures, then comes insecurity and generally disaster.

In an elementary course of mathematics there is a natural order of sequence, from which no great deviation can well be made: and this is so well known that I hardly need to name the order, except to fix our thoughts upon a few points in passing. The old order, arithmetic, algebra, geometry, trigonometry, analytical geometry, descriptive geometry and infinitesimal calculus, is probably good enough. Algebra and geometry may be pursued simultaneously to some extent, as also may analytical and descriptive geometry. I think I am correct in saying that some of these branches of mathematics, throw about as much light backward as forward. For instance, algebra illuminates arithmetic with greater splendor than the latter can return, although their natural order in the course cannot be inverted.

Algebra should not be dropped as soon as the binomial theorem is committed to memory, but should be studied to the bottom of the last page of any good text book. Formulæ for interpolation and for the summation of series, find frequent application in the work of an engineer seeking to simplify tedious computation. The theory of logarithms should be thoroughly understood, and the theory of equations should not be abandoned till the learner knows that "the general algebraical solution of an equation of a degree above the fourth is impossible," but that he can solve any numerical equation by Horner's method.

In geometry omit nothing that the standard text book contains, and be certain that you ponder the logic which leads to the determination of the ratio of the circumference to the diameter, till you can let the question rest forever after. There are some things as well known now as they ever can be, to finite understandings; and the ratio of the circumference to the diameter of a circle is one of them. For we can find it to any degree of exactness we please: and at least two German computers have been pleased to compute it, by different formulæ, to the 200th decimal place, with results identical. And they only stopped at that point because they pleased to do so. Another known and fixed thing is this: "Perpetual motion" will not be discovered nor invented prior to the discovery of a fault in the law of the "conservation of energy."

I make this apparent digression in order to show that he who gets a clear understanding of the course of study I am naming will not thereafter waste his valuable time in pursuit of impossibilities and vagaries. But why need I dwell to emphasize in detail the necessity of a thorough knowledge of trigonometry, both plane and spherical; of analytical geometry, in spite of its detractors, and of the infinitesimal calculus, or

the science of continuous numbers, when it is absolutely impossible to read the best works on mechanics and on engineering without such knowledge.

Let us, then, assume that the intellectual field of the pure mathematics, whose truths and utterances are independent of matter, has been well cultivated, while we go on to note the growth and quality of the harvest. If I may be allowed to continue the figure, I would say that the seeds to be cast into this prepared intellectual field are the units of force, time, and velocity, which at once burst forth into all the fullness of Analytical Mechanics, whose teachings would still be independent of matter could we detach force from its only cause manifested in nature or known to man. Hence, the "full corn in the ear" is mechanics applied to the material universe, and especially so far as we are now concerned, applied to supply the wants, comforts, and conveniences of mankind. This, indeed, is a part of that "fruit" which Bacon admonished and instructed men to cultivate.

We come, then, to note those physical sciences that cannot be neglected by the young engineer, who should know, so far as may be known, the characters of and the laws governing the subject matter to which he is to apply his mechanics: because certain constants which have entered into his analytical equations must now have values assigned to them, which values can only be ascertained by careful observation and experiment upon the subject material.

Among these contributory sciences are Natural and Experimental Philosophy, or Physics, as it is now called: Astronomy, Chemistry, Geology, Mineralogy, and Botany: yielding, in their respective ways, among countless other things, the law of universal gravitation and the acceleration of gravity upon the earth: the power of finding your true geographical position, and the curvature and direction of the meridian: the composition and properties of iron and steel; the nature of sites where important foundations are to be made stable; and the character of the stone and timber that a given structure requires.

Notice that I do not say the young engineer should aim to be a profound physicist or astronomer, a practical analytical chemist, nor an eminent geologist, mineralogist or botanist, but that he should have sufficient elementary knowledge upon these subjects for the proper practice of his profession. For instance, I do not expect the engineer to make chemical analyses of the samples of iron or steel he may wish to examine chemically; this work should be intrusted to a qualified chemist: but the engineer must comprehend the results of the analysis if he would benefit by the test, which he cannot do without some knowledge of chemistry.

That part of the engineering course which I have thus far sketched I hold to be alike needful to all young men who are aiming to enter any one of the various departments of engineering. From this point onward the course should be especially adapted to supply the student with the knowledge and training required by the particular department chosen.

But there is not now time to examine these special courses of study and practice which give us the classes of engineers known as the civil, mechanical, steam, hydraulic, mining, etc., and I will simply give the

list of the kinds of work for which, so far as I know, all the leading engineering schools propose to qualify their pupils. And from this list we may infer the character of further studies proper for the end in view. I quote from the *Engineering News* of February 26th, 1881, the "specialties of engineering practice" for which the Rensselaer Polytechnic Institute of Troy, New York, aims to prepare its graduates:

"The location, construction, and superintendence of public works, such as railways, canals, water-works, etc.; the design, construction, and management of mills, iron works, steel works, chemical works, and pneumatic works; the design and construction of roofs, arch bridges, girder bridges, and suspension bridges; the survey and superintendence of mines; the design, construction, and use of wind motors, hydraulic motors, air engines, and the various kinds of steam engines; the design, construction, and use of machines in general, and the determination of their efficiency; the survey of rivers, lakes, and harbors, and the direction of their improvements; the determination of latitude, longitude, time, and the meridian in geographical explorations, or for other purposes, together with the projection of maps; the selection and test of materials used in construction; the construction of the various kinds of geometrical and topographical drawings."

A moment's reflection upon this broad and diversified field of engineering practice will suffice to show us how numerous and varied are the special studies to be added to the general course I have indicated, and how much must be known by the engineer that cannot be learned from books and the teachings of the average professor, but must be sought in the manufactory, the workshop, and in existing examples of engineering work, in order to know how the practical difficulties of construction, erection, and maintenance have best been overcome hitherto, and so avoid wasting time in repeating old experiments, time that would be better employed in improving the best existing practice, if possible.

Notwithstanding the formidable number of studies implied in the foregoing list of "specialties of engineering practice," I would suggest a few others which are not therein necessarily implied, but which in the best institutions are assumed to be prosecuted by the student, more or less completely, in some part of his course; and which certainly cannot wisely be neglected by engineers.

A sound knowledge of the correct use of his native language, such as implies an acquaintance with many of the best writings published in it, will prove to be of great advantage to him who not only must originate schemes and methods of carrying them out, but who is often compelled to demonstrate the desirableness and feasibility of his project, before he can enlist the capital of individuals or of nations in its execution.

In our day the world sees two engineers acting rather in the capacity of diplomatists, importuning nations for aid to make real the vision of Columbus, who saw ships moving westward from the pillars of Hercules to the far off Indies of the East. The qualification of the diplomatist and the advocate I do not urge upon the engineer, while I do insist upon such use of language as shall fitly express the thought intended to be communicated.

The "dead" languages and living foreign tongues are not absolutely

essential to the engineer; although the former have made large contributions to modern speech, and in some of the latter are published the most profound mathematical and scientific researches. However, the English-speaking engineer will be greatly benefited by being able to read French and German scientific works, notwithstanding it is to some extent true that the formulæ of science, like the musician's score, constitute a universal language that needs no translation.

Another acquisition greatly to be desired by the civil engineer is a good knowledge of correct art, or in other words, a correct taste in architectural design: that, when several designs are competing for his approval, all having the essential qualities of strength, stability, and permanence, and being within his assigned limit of economy, he may select that one which will be most permanently pleasing to the eye.

It is not demanded that the engineer be a Leonardo Da Vinci, or a Michael Angelo, for the proper prosecution of his profession, but it is insisted that he should be able to discriminate between true and false ornamentation, and never encumber really good work with the tricks and suggestions of depraved art.

Finally, since the engineer is also a man, his intellectual development cannot be complete without a respectable knowledge of the principles of law and political economy, and of mental and moral science, all of which, together with history, he certainly may acquire by a well-chosen course of reading. Let not the engineer, whether he be just on the threshold of his profession, or be far along and bearing the burden of weighty responsibilities, feel discouraged when he considers how far short he is of the complete attainment of this long catalogue of things that go to make up the equipment of the engineering profession in all its branches. Although the broad foundation here laid down gives the engineer both the right and the power to be as discursive as he pleases, yet it is better here, as elsewhere, to act on the principle of "the division of labor," and in the main, confine one's efforts to his own chosen department of engineering. And, if in this department he is poorly qualified, he should not waste time in lamenting over his deficiencies, but should endeavor to ascertain at once his real and true standing and then devote all the time he can command to supply these deficiencies. This will require an indomitable will and a perseverance worthy of a hero, but in the end the reward in power gained will far outweigh the expenditure of will and patience. Nor let the practical mechanic or machinist think himself ignored, or the importance of his calling under-estimated in the foregoing recital. There can be no antagonism between correct theory and correct practice; and any ascertained discrepancy between given theoretical and practical work, will, if traced to its source, lead to the correction of one or both. The practical maker of machines cannot afford to determine their proportions by expensive tentative methods, when the engineer could give them to him by the simple solution of a few equations. Nor can the engineer bear the waste of time and the chagrin caused by his making specifications that cannot be executed except on paper.

I hold it to be a chief advantage of a club like this that it brings together those who make and those who execute specifications, for their

mutual improvement; and not that it publishes to the world a vast number of papers, unless their matter is mainly new.

EXPERIMENTAL STUDY COMPARING THE INFLUENCE OF EXPANSION IN SIMPLE AND COMPOUND ENGINES.

By M. HALLAUER. Read before the Industrial Society of Mulhouse, December 30 1878.

(Translated from *Bulletin of the Industrial Society of Mulhouse*, for May—June, 1879. by CHAS. A. SMITH, Member of tne Engineers' Club of St. Louis.)

CONTINUED.

INFLUENCE OF VARIABLE EXPANSIONS UPON THE WORKING OF STEAM IN WOOLF ENGINES—THEIR UTILITY FROM THE POINT OF VIEW OF CONSUMPTION.

The exposition of the very complex phenomena which absorb us, the study of which should be made as clear and as easily grasped as possible, induces us to give in Table III. a summary of the principal results which form the basis of our discussion.

The action of the iron upon the fluid which it incloses is so well established, and the result of Hirns' labors on heat engines is such that it naturally follows that variable expansions modify the nature even of the work of steam. We introduce into the cylinders different weights of steam, different quantities of heat, therefore it is not astonishing to see during expansion variations in the direction and amount of the changes of heat. But that which should be useful in practice is the experimental determination of these changes, followed by the results of their analysis and their justification. We shall fall perchance on facts at first inadmissible like those we found for expansion 13, and find the natural explanation in the most profound study of the phenomenon, a purely physical study.

The paradoxical fact which we will recall is presented then in experiments C and D upon each of the Malmerspach engines working with expansion 13, and with full pressure more than one-half of the stroke in the small cylinder. During the expansion in the large cylinder a portion of the steam existing at the end of the stroke of the small piston is condensed—Experiment C., 4.8 per cent.; Experiment D., 5.2 per cent. The internal heat has diminished $U_2 - U_1 = \times 23.53$ c and 25.59. But the work of expansion in the large cylinder has demanded and absorbed 24.9 c and 25 c, that is to say nearly the same amounts for this period of work There was no heat furnished from outside, the jacket appears to have yielded nothing, was it not working during this period of expansion?

This hypothesis is inadmissible, for we have seen that it contradicts a well-known principle of physics relative to the transmission of heat; the exchange of heat across the sides of the cylinder should be more rapid with the greatest difference of temperature between the two surfaces, for one of them is in contact with the jacket steam at boiler pressure, and the other possesses the temperature of the cylinder steam at a much lower pressure. We would remark that the difference of temperature is not the only factor which can accelerate this transfer; the layer of water,

TABLE III.

PER SINGLE STROKE.	MALMERSPACH ENGINE.			MUNSTER ENGINE.			HORIZONTAL ENGINE.	
	E	C	B	III.	II.	I.	I.	II.
No. of expansions	28	13	6	7	7	7	6	6
Ind. H. P. on pistons	143	215	201	185	267	347	130	181
Dry steam per hour per total H. P., kilograms	6.731	6.878	7.402	7.384	6.945	7.112	7.290	7.328
Back pressure work, per cent. of total work	18.6	15.6	16.04	24.10	20.52	17.43	20.06	17.30
Dry steam per hour per Ind. H. P., kilograms	8.273	8.149	8 847	9.730	8.739	8.614	9.120	8.614
Mechanical efficiency, per cent	82.7	86.1	85.6	78.3	84.3	87.3	86.1	89.0
Dry steam per hour per net H. P., kilograms	10.019	9.465	10.301	12.411	10.357	9.864	10.563	9.678
Per cent. priming or water carried over	5	5	5	2.3	2.9	2.8	3	4
Per cent. steam condensed in jackets	8.5	7.7	5.1	10.4	9.0	8.6	10.0	7.5
Per cent. water in steam at cut-off	40.0	23.7	12.8	21.17	14.21	16.17	11.20	10.80
Per cent. " " " " end small cylinder	19.1	13.1	....	....	....	....	....	....
Per cent. " " " " " large "	17.6	17.9	11.15	7.39	5.39	6.60	5.34	4.5
Change of internal heat during expansion $U_0 - U_1$, calories	− 25.88	+ 1.24	+ 7.17	− 31.89	− 16.58	− 17.40	− 3.63	− 6.12
" " " " in small cylinder $U_0 - U_2$ "	− 29.37	− 22.29	....	....	....	....	....	....
" " " " " large " $U_2 - U_1$ "	+ 3.49	+ 23.53	....	....	....	....	....	....
Rc or cooling due condenser in calories	19.34	31.44	8.44	13.48	6.65	21.89	1.95	1.16
Rc in per cent. total heat brought to engine	7.8	8.3	2.10	3.5	1.32	3.38	1.19	0.5

which covers the internal surface has also its influence; it augments the rapidity with which heat is brought to the inner surface: it provokes a proportionally greater action in the jacket, as we will prove by the figures of Table III.

How can it be, then, since the jacket is in the best possible condition to furnish heat, that it appears to be inactive? This apparent anomaly has a very simple cause—the action of the surfaces at the commencement of the stroke of the large piston.

I established in my paper of 1878 that at the first tenth of the stroke of the large piston, a moment when the dry steam is nearly equally divided between the small and large cylinders, there is one-half at least of the fluid deposited as water upon the walls of the large cylinder, if we mark then that at the end of the first tenth of the stroke of the large piston the large cylinder contains more water than steam; that is, that the first part of this stroke the condensation has been very considerable, while the cooling due the condenser has been only 1.3 per cent. loss.

The same fact is presented for experiments C and D in stronger propor-ions yet; since by the coôling due the condensor the heat taken from the iron during exhaust is 8.3 and 9.9. It is upon this water which causes the surface that the jacket acts, and since it cannot evaporate a sufficient quantity, the internal heat at the end of the stroke is less than at the end of the stroke of the small piston. Such is the particular circumstance which the five experiments made upon the coupled engines at Malmerspach present to us; it is not the first time we have had occasion to remark it. I have already noted it in the experiments made on the Munster engines in 1876, working with little compression in the clearance spaces.

Let us indicate the modifications which a variable expansion brings to the transformation of steam and to the action of the jacket.

The three experiments B, C, and E., the first the result of a very slight expansion in the small cylinder where the steam has been admitted nearly all the stroke, with a total expansion of 6. The Ind. H. P. only reaches 201. To do this feeble work the steam pressure had to be throttled, for we see with 13 expansions and full pressure a work of 215 H. P., a greater load in spite of the less introduction.

In these conditions the weight of steam condensed during admission is small, 12.8 per cent., less the water carried, over 5 per cent. = 7.8 per cent. deposited upon the surface. The jacket yields proportionately less heat, for it only condenses 5 per cent. of the steam brought to the engine. We remark that in spite of the condensation which took place at the first stroke of the large piston, the proportions of water are within 1.3 per cent. the same at the beginning and end of the expansion, and that the cooling due the condenser is small enough, 2.1 per cent. of the entire heat brought the engine. In spite of these conditions, which appear advantageous enough, the consumption per total H. P. is 7,402 k, while those of C and E are 6,878 k, and 6,731 k, that is to say, by 7 and 9 per cent.

Is this the gain realized by the expansion? This we shall see.

Experiment C, with introduction of half stroke in the small cylinder, presents a condensation of 23.7 — 5 = 18.7 per cent. during the admission, but the proportion of water which is found is partly evaporated

during the first part of the expansion, and changes from 23.7 to 13.1, the internal heat increases by 22.29 c. in spite of the heat which this firs work of expansion requires. The transfers of heat are then very energetic in the small cylinder instead of nearly nothing, as in the case of experiment B. Such is the first modification caused by expansion 13 with an introduction of half stroke in the small cylinder.

Passing to the results of experiment E, expansion 28, this modification is much more marked. The proportion of water at the end of an introduction of $\frac{1}{5}$ stroke of small cylinder is 40 per cent., and 21 per cent. evaporates during the first expansion, and the internal heat increases 29.37 c; in short, we see that as the expansion in the small cylinder is increased the transfers of heat are increased.

On the other hand, the action in the large cylinder follows another law. We have seen, that with nearly full stroke introduction in the small cylinder, experiment B, the internal heat remains nearly stationary, diminishing by only 7.17 c between the ends of the stroke of the small and large pistons. The same fact is found in experiment E, 28 expansions. But we have seen above that the intermediate experiments C and D show us a considerable fall of internal heat, a fall sufficient to furnish to the work of expansion the number of calories which it requires. Here there is, then, as in the small cylinder, an increase in the transfers of heat from experiments B to C, but a decrease follows the minimum, which appears toward expansion 13, to which is due that the internal heat U_1 is increased relatively to the final internal heat U_2 of the small cylinder.

By considering only the phenomena of the total expansion from the moment that it commences in the small cylinder to the end of the stroke in the large cylinder, we see that the differences of internal heat are continually reversed; this shows that the transfers of heat are greater and greater as the expansion is increased. Thus for experiment B the final internal heat U_1 is 7.17 c less than U_0 at the end of admission; for experiment C this difference is only 1.24 c; while for experiment E the difference is reversed, and the final internal heat is 25.88 c larger than at the end of admission. The qualities of heat furnished by the jacket, the proportions of steam condensed in the small cylinder during admission, which transforms the inner surface of the cylinder into a reservoir of heat, and the internal heat, all these values are intimately connected together, as we have already said many times; they depend the one on the other; and are in some sort the various manifestations of the same thing; also we see them changing in kind the condensation in the jacket and small cylinder during admission increase with expansion furnishing thus more heat in proportion than is measured by the expansion, and considerably more.

This law appears to be general in Woolf engines, not only with variable expansions, but for fixed expansions and variable powers obtained by throttling the steam. The experiments upon the Munster engine show us that with 185 H. P. the final internal heat U_1 is 31.89 c more than the initial internal heat U_0 at the end of admission, while this difference is only 17.40 c for the experiment with 347 H. P. Meanwhile examining more closely the figures of the two series of experiments at Malmerspach and Munster, we discover one point which merits being brought into

light. The differences $U_0—U_1$ are close together for experiments I. and II., —17.40 c and 16.58 c, more alike than B and C, 7.17 c and 1.24 c, which differ much from E, 25.88 c. This leads us to believe that in the limits of expansion and throttling of experiments I,, II., B. C, the differences of internal heat remain nearly stationary: they only commence to increase rapidly when we go beyond 13 expansions and throttle below 267 H. P. of experiment II.

Finally we see for all the Munster experiments of 1877 the final internal heat U_1 is greater than the initial internal heat U_0. If this fact is the reverse of what was produced upon the same engine in 1876, it is that at that time the engine was differently regulated, the compression in the clearance space was much less. The increase of compression diminished greatly the lead influence of the clearance. This realized an economy and the result betrays itself by an increase in the final internal heat. It is not necessary to believe that this is always the characteristic sign of a better working of the engine. We have in effect experiments C and E, of which the consumptions vary only 2.1 per cent. when the differences of internal heat $U_0 - U_1$ are 1.24 c, and — 25.88 c. On the other hand, experiments I. and II. give $U_0 - U_1 =$ —17.40 c and 16.58 c, and meanwhile the consumptions vary 2.4 per cent., the least being for experiment II. throttled to 267 H. P.

Summing the effects of a greater total expansion, commencing in the small cylinder and placing parallel to them the effects of the same kind produced by throttling, reducing the indicated work in the same proportion that the change of expansion did, the best experiments are C and E, expansions 13 and 28, and experiments II. and III., and the same expansion 7. The Ind. H. Ps. are nearly in the same ratio,

$$\frac{215}{143} = 1.5 \qquad \frac{267}{185} = 1.44$$

When the expansion changes from 13 to 28 the condensation in the small cylinder during admission increases from 23 to 40 per cent.; the heat given to the iron is increased. The jacket also gives a little more heat, but the greater part of this heat is restored in the small cylinder itself. It furnishes there more heat than is needed for the work of expansion, for the evaporation of 10 and 21 per cent. of the water deposited upon the surface. This is proved by the increase of internal heat by 22 and 29 c at the end of the stroke of the small piston. In the same circumstances, throttling with nearly full admission in the small cylinder, experiments II. and III., the communication between cylinder and boiler is open also. The proportions of steam condensed only vary from 14 to 21 per cent., which shows a very different kind of working. The steam passes then to the large cylinder; it is in this that the transfers of heat are found which did not take place in the small cylinder. The internal heat is increased during the expansion 16 and 31 calories; 9 and 14 per cent. of the water is evaporated. On the other hand, with 13 and 28 expansions, commenced with cut-offs at one-half and one-fifth in the small cylinder, the reverse action took place. The energetic changes are less in the large cylinder than in the small cylinder. This is a fact which will serve us later in comparing single and double cylinder engines.

Experiment B seems to contradict this law, for the internal heat diminishes 7 calories from the beginning to the end of the expansion, and the proportions of water are nearly the same, 12 and 11 per cent. This is due to two causes, the influence of a distribution with very little compression, and the less effect of the jacket, where there is only 5 per cent. of the weight of the steam condensed: but it is none the less true, that the heat furnished by the jacket has been during the expansion in the large cylinder. Before attacking the question from the practical industrial side let us seek to render an account of the advantages of expansion, considering only the work of the steam: that is to say, abstracting imperfections of vacuum and frictions of the engine.

In principle, theory has conducted M. G. Zeuner to recommend very prolonged expansions. M. G. A. Hirn, on the contrary, holding account of the practical conditions imposed on the engine, engaged the adaption of moderate expansions. We shall see that these two opinions which appear contradictory are both sanctioned by our experimental researches when properly analyzed. That the work of M. Leuner supposed that the cylinder was non-conducting, and the closed cycle perfect, but the result exists that the cycle is interrupted by the conditions in which we place our Woolf engines. We should naturally expect to see the benefits of expansion considerably diminished by the transfers of heat to the internal surfaces: but the difference is great enough to allow us to affirm the law.

Commencing by comparing the cost per total H. P. of experiments I., II., III., C and E, experiment I., 347 H. P. expansion 7, has been made made with an initial pressure near that of C and E, but it is experiment II., made with a lower pressure, which presents the minimum cost, 6.945 k. This is due to some particular circumstance which we have not been able to bring out, and which causes the cooling due the condensor to be least for experiment I., while to compensate this action we take for the consumption for 7 expansions the mean of I. and II. 7.028 k. The cut-offs for expansions 7, 13 and 28 are in the ratio of 1, $\frac{1}{2}$, and $\frac{1}{4}$; the costs are 7.028 k, 6.878 k.; and 7.731 k. a decrease of 2.2 per cent. or an expansion four times as great procures 4.4 per cent. gain. The law of M. Leuner is then found verified experimentally in Woolf engines. It is to be noted that the disturbing effect of the surfaces does not reverse this law, for in the method used to determine the cost this influence is fully accounted for. The cost for experiment III., 185 H. P., 7 expansions, is 5 per cent. inferior to that of I. II. Whence we conclude that it should have a marked advantage of about 10 per cent. in replacing by more expansion too great a lowering of initial pressure.

We have left to one side experiment B made with the same engine as C and E, for two motives which appeared to us ought to exclude it: in the first place the jacket did not yield enough heat. And then the valves are set with a compression not sufficient to help the clearance. But everybody knows that one of the effects of a prolonged expansion is to extenuate in part the pernicious effect of the considerable waste spaces of the Woolf engine.

The cost of a net H. P. brings us the modifications of the more or less perfect vacuum which falsifies the preceding law, thus experiments I.

and II. differ in reverse order 1.4 per cent., and C and E, which vary 1.5 per cent.

Finally the cost of a net H. P., upon which the combined effects of poor v cuum and friction give the following results: Experiment I., 9.864 k; II., 10.357 k; III., 12.411 k; C, 9.465 k; E, 10.019 k. The least is experiment C, expansion 13; it only varies 5½ per cent. from E, expansion 28, and 4 per cent. from I, expansion 7, full pressure. This justifies the proposition of M. Hien. There remains to calculate the dimensions to be given to engines and the frictions which result, the foreknowledge of the interrupted cycle and the moderate expansion. In a word he says: "For reasons of practical fact the steam engine with broken cycle and moderate expansion works better, *notwithstanding its faults*, than the engine working with the perfect cycle," without regard to first cost.

Experiment III., 185 H. P.; expansion 7, pressure much reduced, differs 24 per cent. from the corresponding experiment, E, expansion 28, full pressure. This difference is due the vacuum and friction. If the horizontal engine occupies the last rank, it owes it to the small compression, its vacuum and frictions. Its inferiority is only 2 per cent. relatively to the corresponding experiments II. and B., and 6 per cent. referred to the experiment with greatest power, I., 347 H. P.

The practical consequences of these collected researches upon the Woolf engine may be stated thus:

First. From the total point of view, considering only the best utilization of the heat brought to the engine, we can reduce the maximum work with 5 kilos. pressure. For example (70 pounds), expansion 7 to ½, by diminishing the initial pressure, and there results a loss of 5 per cent. of the cost of a total H. P.; while by reducing the introduction in the small cylinder, we can gain 4½ per cent. of the same cost.

Second. When one is obliged to reduce the work one-half, whether because of a change of load or because used with water power, we can make a practical gain of 10 per cent. at least by replacing the throttle by a variable cut-off in the small cylinder. We suppose it well understood that the back pressure work remains the same in the two cases. The friction is naturally the same, since the work is the same.

Third. The engine working near its full load, it is possible to vary the work 10 per cent. more or less, without any notable change in the economic régime due to expansion or change of pressure. There follows the disposition we have already remarked: an expansion variable by hand and a governor throttle valve, which will answer all requirements, and is the most simple and durable.

[NOTE.—This is all one paper not several as printed by mistake at the head of the different portions *pp*. 329, and 345. The proper names are M. G. A. Hirn not Hein and G. Zeuner not Leuner as enorneously printed in some places, *p*. 298. The expansion gear mentioned on *p*. 300, is Correy's not Comey's.]

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

CIVIL ENGINEERS CLUB OF CLEVELAND.

JUNE 13, 1882:—Regular meeting held. In the absence of both President and Vice-President, Mr. Chas. Latimer was called to the chair. The Recording Secretary not being present, Mr. J. S. Oviatt was elected Secretary, *pro tem.* Minutes of last meeting read and approved. Report of special committee to arrange for the contemplated visit of Pittsburgh Society was received from Mr. Morse, and the following resolution adopted :

Whereas, The Engineers' Club of Pittsburgh purpose visiting Cleveland some time during this month, and also to extend their trip to Kelly's Island, or to take an excursion on the lake, and have requested that this club join them ; therefore, be it

Resolved, That the members of this club extend to the Pittsburgh club a cordial welcome to visit our city: and be it further

Resolved, That all members of this club who can, shall turn out and give to the visiting club a hearty welcome and extend to them such courtesies as shall make their visit one of interest and pleasure, and that if an excursion shall be taken on the lake, all members of this club join in the same; and in the furtherance of such object, the following resolution was adopted by the club:

Resolved, That six members be added to the former special committee, the members to be chosen by the old committee.

The names of Edward H. Jones and Edwin H. Martin were favorably reported upon by the Committee of Membership, and upon motion were elected active members of the club.

On motion of Mr. Whitelaw the Secretary was ordered to return the thanks of the club to the American Society of Civil Engineers for its kind invitation to attend its annual convention, held at Washington from May 16 to 19, 1882.

Prof. John Eisenmann, of the Case School of Applied Science, then read a very interesting paper on the United States Lake Survey, giving the methods of work, illustrating the same with drawings. At the conclusion he was tendered a vote of thanks for his able paper.

A vote of thanks was extended to the managers of Case Library for the renovation of the club room.

On motion the club adjourned, to meet on the second Tuesday evening in July.
J. S. OVIATT, Secretary, *pro tem.*

JULY 11, 1882:—Regular meeting held; President Wilson in the chair. Minutes of last meeting read and approved. Mr. Rawson made a report of work done by the Board of Managers of the "Association of Engineering Societies" on joint publication.

On motion the following resolution was adopted: *Resolved*, That the Treasurer be and he is hereby authorized to pay such sums as may from time to time be called for by the Board of Managers for the purposes of joint publication, such assessments in the aggregate not to exceed $4.00 per member as represented by the present mailing list, without further authority from the club.

The committee appointed April 2, 1881, to report amendments to the By-Laws if deemed necessary, having made no report, was relieved from further duty, and the following resolution in reference to the same was adopted: *Resolved*, That the Constitution and By-Laws be referred to a committee of five members, of which the President shall be one, and ex-officio chairman, who shall report

at their earliest convenience such changes, if any, they may think desirable; the members of such committee to be appointed by the President.

The Committee on Revision consists of the following persons: Col. J. M. Wilson, chairman, A. Mordecai, M. E. Rawson, Charles H. Strong and J. N. Richardson.

The following resolution by A. Mordecai was lost. *Resolved*, That when this club adjourns, it be to September 12, 1882.

Mr. Robert French, corresponding member, and Chief Engineer of the Cleveland, Mount Vernon & Delaware Railroad, read a paper on the location of frogs, switches and sidings; after which the club tendered him a vote of thanks, and adjourned. M. W. KINGSLEY, Rec. Secretary.

AUGUST 8, 1882:—Regular meeting held; President Col. J. M. Wilson in the chair. Minutes of last meeting read and approved.

The Committee on Membership reported favorably upon the request of Rev. J. W. Browne for withdrawal from the club, and on motion the request was granted.

The President read a letter sent by him to Mrs. A. L. Holley, when sending copies of the Association JOURNAL containing Mr. Holloway's remarks on the life of her husband, A. L. Holley.

The President also read Mrs. Holley's reply to the same. The club voted that both letters be spread upon the club records.

Professor A. L. Arey, member of the club, then read a paper on the "Dynamo-Electric Machine," which was accompanied by experiments with electrical apparatus, at the conclusion of which he was tendered a vote of thanks.

[*Adjourned.*] M. W. KINGSLEY, Rec. Secretary.

SEPTEMBER 12, 1882:—Regular meeting held, with President Wilson in the chair. The names of Daniel Appel, Ambrose Swasey, Worcester R. Warner, Horace C. Thatcher and George H. Breyman were received for active membership and referred to the Membership Committee.

The Committee on Membership having reported favorably upon the petition of Harry B. Strong, he was duly elected an active member of the club.

The President read the report of the Committee on the Revision of the Constitution and By Laws.

The report was received and filed, and ordered brought up for discussion at the October meeting.

Mr. Wm. M. Barr read an able paper on the "smoke nuisance," after which the subject was discussed by Professor Arey and Messrs. Wood, Whitelaw, Halloway, Barr and others of the members, and by Professor Robinson, of the Ohio University, and Mr. Kent, of Pittsburgh, who were present as visitors.

Col. John M. Wilson then tendered his resignation both as President and member of the club, the former to take effect immediately, and the latter March 1, 1883, owing to his promotion and transfer from the U. S. Harbor Improvement in this district, to Gov. Headquarters at Washington.

Mr. Rawson moved that the resignation be not accepted, and that Col. Wilson be requested not to withdraw his name as President of the society until the end of the fiscal year.

Mr. Halloway moved to amend, with Mr. Rawson's consent, that the resignation of Col. J. M. Wilson be not accepted, and that a committee of three be appointed to prepare resolutions suitably expressing the regret felt by the club on account of his inability to preside over our future meetings. The resolution as amended was adopted, and Vice-President Halloway requested to name the committee.

In answer to an inquiry, the President stated that he expected to be present at the October meeting. Mr. Halloway said that such being the case, he would name the committee at the next meeting.

The Programme Committee was requested to provide for the further discussion of the Smoke Nuisance at the next regular meeting. On motion, the club adjourned. M. W. KINGSLEY, Rec. Secretary.

WESTERN SOCIETY OF ENGINEERS.

AUGUST 1, 1882 :—The 151st meeting was held at 4 P. M.

Mr. Liljencrantz was called to the chair.

The Secretary presented the application of Mr. John J. McVean, Chief Engineer Detroit, Lansing & Northern Railroad, to be admitted as a Member, endorsed by Messrs. Pope, Baker and Morehouse.

It appearing that no quorum was present, at this point, the meeting adjourned.

AUGUST 15, 1882 :—The 152d meeting was held at 4 P. M., Vice-President Cregier in the chair.

The minutes of the preceding meeting were read and approved.

Application to be admitted as a Member was presented from Mr. Charles S. Pease, U. S. Civil Assistant Engineer, Council Bluffs, Ia., endorsed by Messrs. Bradley, Cooley and Seeley.

Mr. Liljencrantz, for the Committee on Publication of Proceedings, reported that the Committee recommended that the proceedings be published as soon as possible after each meeting, and a copy mailed to each member.

It was voted that the report be accepted and the recommendation of the Committee adopted.

It was also voted that the Manager representing this Society in the Association of Engineering Societies be, and is hereby, requested to have two copies of the JOURNAL furnished as issued, for the Society's library.

[*Adjourned.*] L. P. MOREHOUSE, Secretary.

OCTOBER 3, 1882 :—The 155th regular meeting was held at 4 P. M., in the rooms of the Society.

In the absence of the President, Mr. Benezette Williams was called to the chair, and the Secretary being also absent, Mr. Liljencrantz was appointed to act as Secretary *pro tem.*

The proceedings of the 151st and 152d meetings were read and approved.

Application for membership was presented from Mr. Samuel N. Hartwell, General Manager of the Chicago Lathe Co., endorsed by Messrs. J. H. Raymond, Samuel G. Artingstall and Benezette Williams.

The following gentlemen were elected members : Mr. John J. McVean, Chief Engineer Detroit, Lansing & Northern Railroad, and Mr Charles S. Pease, U. S. Civil Assistant Engineer, Council Bluffs, Ia.

A communication was received from Mr. John W. Weston, editor of the *American Engineer*, tendering his resignation as Librarian, the pressure of other duties making him unable to attend to said office in a manner satisfactory to himself.

The letter was read to the Society and the resignation accepted.

Mr. Liljencrantz was elected to fill the vacancy during the unexpired term.

Mr. D. J. Miller, Engineer of the Chicago City Railway Company, read a paper on "The Chicago Cable Roads." The paper was illustrated by a number of drawings, and was subsequently thoroughly discussed by the members, among whom Mr. Wright, Engineer of the North Chicago City Railway, endeavored to demonstrate that the horse railway is equally cheap, furnishes as rapid transit, is less dangerous, and gives, all considered, as much general satisfaction, when compared with the cable road.

[*Adjourned.*] G. A. M. LILJENCRANTZ, Secretary *pro tem.*

[At the 153d and 154th meetings no quorum was present and no business was transacted.]

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. I. OCTOBER, 1882. No. 12.

This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

CHICAGO CABLE ROADS.

By D. J. Miller, Member of the Western Society of Engineers.

[Read October 3, 1882.]

The cable railway system of our city has attracted considerable attention for the past year, not only in Chicago, but in nearly all cities of the Union, if we may judge from the numerous inquiries made and the number of railway representatives who have visited Chicago for the purpose of obtaining information upon this subject. For a distance of over 4 miles we have a system of transit which is certainly a great improvement over previous methods of street-car locomotion. I am well aware that I am unable to do justice to a theme of such magnitude, and will only endeavor to give a brief description of some of the principal points connected with the work. With all motors the carrying power is of necessity limited, but with the cable system it is, comparatively speaking, unlimited, and the tractive power of the cable, when operated by a stationary engine, gives this system an advantage over all others, as no dead weight is required to procure adhesion to the rails. It seems almost incredible, but is nevertheless a fact, that the State street road, now in operation, has a carrying capacity of ten thousand passengers per hour, and even this enormous traffic will not overburden the cable.

Fig. 1 is a drawing of grip and grip-car, used by the Chicago City Railroad Company, and the position of the cable in the gripper *G* will be readily understood by reference to the same (I wish to give Mr. Oscar Lundquist credit for making this drawing for me).

When the car is not in motion the cable passes freely through the jaws of gripper, in which wooden blocks are placed. As these jaws are forced together the blocks are brought in contact with the moving cable and the friction starts the car with an easy movement, provided the lever is held by a careful operator. Again referring to the drawing, the dotted line *l* represents the line of cable when not in grip, the gripper having a clearance of 2¼ inches above carrying pulleys *P*. When held in the jaws the

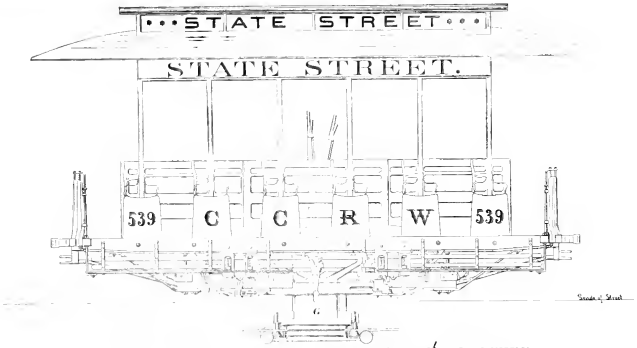
cable is 13 inches below the surface of street, and when on pulleys P is 8 inches lower, or 21 inches below the surface of street.

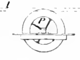
The greatest expense incurred in this system is in road-bed and tunnel construction, and, although several cable roads have already been built, but few of them have cost less than one hundred thousand dollars per mile of double track. Probably this figure will be considerably reduced in time, as the system becomes more generally used and engineers more experienced in the work.

Fig. 2 is a cross section of track at curve, as used in this city. The road-bed and tunnel construction is the same as for straight tracks, except that conical pulleys h are used on curves, for holding the cable on as direct a line with gripper G as may be possible. These conical pulleys are placed 8 feet apart, on a radius of from 40 to 60 feet. The angle iron a is bolted to the slot rail inside of tunnel, to assist in holding the gripper in position. There are various designs for road-bed and tunnel construction, no two roads having as yet been built exactly alike, and many designs are suggested by different individuals; some express a preference for a brick tunnel in place of concrete, and others advocate the use of a cast iron tube; but it would be necessary to take into consideration the climate, nature of soil, and grade of streets, before deciding which might be best for any particular locality. In Chicago, the streets are nearly level, and drainage must be secured for tunnel; consequently a greater depth is needed than where streets are not of uniform grade. The tunnels here are from 3 feet and 4 inches deep at the summit to 3 feet and 7 inches at catch basins; and this, with grade of street, gives a fall of $3\frac{1}{3}$ inches in 100 feet. The catch basins are located every 300 feet, and connected with city sewers by overflow pipes. There is no objection to a deep tunnel, and, as in some of our severe winters it will be important to dispose of the water which may accumulate in the tunnel, if drainage be insufficient trouble may be expected.

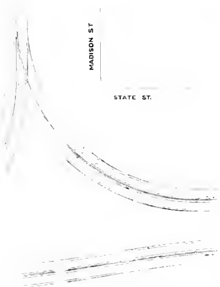
Wabash and Cottage Grove avenues will be in operation about the last of November of the present year. These lines are operated from the building at corner of State and Twenty-first streets, and the cables receive motive power from the machinery running State street lines. Cables for operating these avenues must be carried some distance from the building before they are brought into actual service. Cottage Grove avenue line commences at the intersection of Cottage Grove avenue and Twenty-second street, about 1,920 feet from the operating room. This line runs south 11,642 feet to wheel vault south of Thirty-ninth street, and then returns, making the total length of cable 27,124 feet. Wabash avenue cable is brought into use at the intersection of Wabash avenue and Twenty-second street, and will run north on Wabash avenue to the centre of the block between Monroe and Madison streets, and then return, and the length of this cable will be 22,873 feet.

These cables are carried from the operating room to their respective lines through a third tunnel between the railway tracks, and where angles are made excavations are provided for the reception of 12-foot sheaves, around which the cables are passed, thus holding them in a direct line from one wheel vault to another.

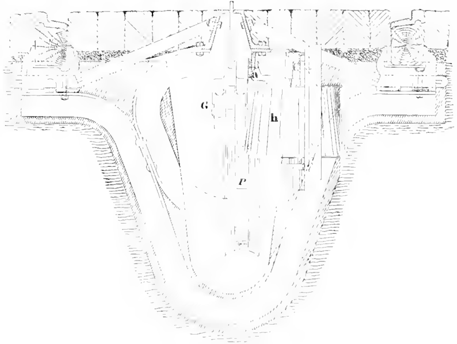




Side Elevation of Grip & Grip Car. **Fig. 1.**



PLAN OF CURVES AND CROSSING



Section of Track at Curve

CHICAGO CABLE ROADS.

To avoid shunting devices in connection with cable trains, a belt line has been adopted, on which State street cars pass east on Madison street to Wabash avenue, then north to Lake street and west to State street, then returning south, making a circuit of three blocks.

This belt line is operated by an auxiliary cable which is propelled by the end wheel, upon which the State street main cable reverses. This transmission of power is effected by carrying the main cable into a vault (see Fig. 3) and passing it around a 12-foot sheave to which a 6-foot sheave is coupled for operating the auxiliary cable at half the speed of main cable.

The arrangement of wheels in the vault will be understood from the illustration given. After the auxiliary cable is carried around the 6-foot sheave it passes to the tension wheel *T*, which keeps the cable taut by means of weight *W*; cars moving north exchange cables at *B*, and those moving south at *E*. Wabash and Cottage Grove avenue cars are to be operated around the above-mentioned belt line by a similar auxiliary cable (driven by Wabash avenue main cable) and return to Wabash avenue by way of Madison street, then south on the return trip. A wheel vault, similar to the one on State street, is located on Wabash avenue for transmission of power to the auxiliary cable, consequently two cables will pass around the belt line in the same tunnel, each operating its own line of cars.

It will be seen that two cables in one tunnel will be taken around the curves at corner of Lake and State streets, also corner of Lake street and Wabash Avenue. Although an arrangement has been designed for this purpose, as it has not yet been tried I deem it best to omit a description.

Railway officials are generally interested, and seem anxious to ascertain the percentage to be saved by the use of the cable system.

Much depends on the manner in which a road is built, for if constant repairs must be made and the same number of horses maintained as if using animal power, it would be a difficult matter to find wherein a saving were effected, but if a road be properly constructed there is every reason to suppose that a gain of from 30 to 50 per cent. would be made where from 200 to 300 horses were needed for the work, and from 60 to 70 per cent could probably be realized on larger roads with heavier traffic by careful and judicious management.

I think the use of duplicate cables would materially assist in the perfection of this system, as in case of accident to one cable there need be no stoppage of the road. The use of a single cable necessitates having horses in readiness for an emergency, and a cable road is supposed to dispense with the use of animal power. If employing two cables it is evident that no horses need be retained, for if one cable be disabled the other could be called into immediate use, or both might be used simultaneously. A road can as well be built for using duplicate cables as for a single one, and the difference in cost of construction would be nothing compared to the benefit derived.

State street is now operated with two single cables, one running north and the other south from the engine house at Twenty-first street.

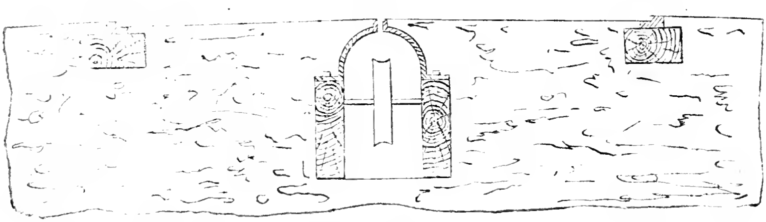
The indicated horse-power of the engines, divided by speed of cables, gives the strain on all the cables as 5½ tons, and if to this is added one-

half of tension weight, we have $6\frac{1}{2}$ tons load for the two State street cables.

If but one cable was used to do the work it would require a rope eight miles long, and I should not consider this length objectionable provided the cable was not overloaded, and, as in this case, the strain is but $6\frac{1}{2}$ tons, and the proper working load of a steel cable of this size ($1\frac{1}{4}$ inches in diameter) is 8 tons, I can see no reason why one cable would not be sufficient. The breaking strain of a steel cable $1\frac{1}{4}$ inches in diameter is 39 tons.

Objections have been made to the use of long cables on account of the sway or variation of speed: but if engines were well governed I do not believe this would be sufficiently marked to be objectionable, and all moving cars would assist in keeping the cable at uniform speed. By doubling the length of the ropes and increasing the number of sheaves, State street could be operated with duplicate cables.

The cable system is not of recent origin, as might be supposed. We find by examining the United States Patent Office records that the first patent of importance was granted on improvements in tracks for a city railway to G. S. Gardner, of Philadelphia, in 1858, and as it may be of



STREET RAILROAD (Patented March 23, 1858, by E. S. Gardner).

interest, I will give his claim in full, with copy of Patent Office drawing The inventor says:

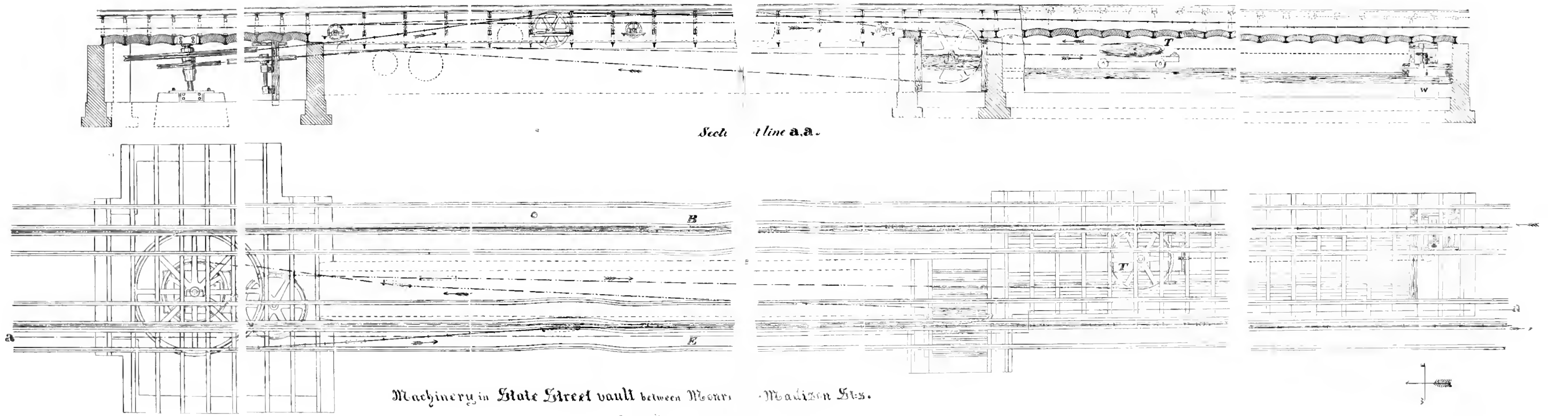
"I claim forming between the rails of a city railroad track, an underground tunnel, and hanging a series of pulleys within the same, said tunnel having a longitudinal slot near the level of the ground, and being otherwise so arranged that a rope may be used for drawing the cars along the track without impeding the passage of vehicles across the same."

There have been over 130 patents granted by the United States Patent Office on cable traction, but I have no knowledge of a patent which covers the system, and a cable road can be built without infringement, although it might not be advisable to ignore all patented improvements.

The numerous fatal accidents resulting from the introduction of this system are to be deplored, but from present indications we believe there will be no recurrence of these misfortunes, as people are becoming accustomed to the cable, and operators more skilled in its management.

No doubt, radical changes will be made in the system, and we may, in the near future, see cable cars operated with comparative safety in our cities at a speed of 10 miles per hour, which is certainly to be desired.

The conversion of these roads from animal traction to the cable system



Machinery in State Street vault between Monr Madison Sts.

Scale

FIG

CHICAGO CABLE ROADS.

was certainly a gigantic undertaking, and required more fortitude on the part of the projectors of the scheme than may be supposed, as there were many obstacles to be overcome, and considerable outlay to be made in experiments, these roads differing in many respects from those previously constructed; but the originators of the project have reason for congratulation, and should receive the gratitude of the public in general for so successfully supplying means of comfortable and easy transit.

THE SMOKE NUISANCE.

By Wm. M. Barr, Member of the Civil Engineers' Club of Cleveland.
[Read September 12, 1882.]

The attractiveness and the beauty of many of our Western towns and cities are greatly marred by the clouds of smoke continually hanging over them, casting a shadow so dense as often to shut out entirely the direct rays of sunlight for several squares in the immediate vicinity of certain manufactories, and especially is this true in those localities where puddling and other kindred operations are carried on.

The cleanliness of the manufacturing towns and cities in the Eastern States contrasts so unfavorably against us that more than a mere apology is due for our general untidiness. Cleveland is entitled to take rank as one of the most beautiful of American cities, and yet there are localities in this city in which the smoke is so dense as to entirely prevent comfortable residence within several squares of certain industrial establishments in which bituminous coal is used as the principal fuel: the result is, as might be expected, depreciation in the value of residence property in that immediate vicinity.

There are some things which must be endured because they cannot be cured, and I have no doubt many persons look upon smoke as a sort of necessary evil; others rather take pride in it, and imagine smoke to be an index to local activity and enterprise. Many persons now engaged in manufacturing have, by long familiarity, become so accustomed to seeing smoke pour forth from their own and other chimneys, that it never once occurs to them that all this annoyance to hundreds and often thousands of residents in the immediate locality is being dearly paid for out of their own pockets.

A manufacturer whom the writer once approached on this subject remarked that, "it was at its worst only an annoyance; there was nothing deleterious about it; persons soon became used to it, and cared little or nothing about it afterwards."

It is true people live near such factories and put up with the smoke and the dirt incident to the locality, but that does not argue in its favor any more than the fact that people will persist in living near ponds and defective sewers argues in favor of bad air and foul gases; but, outside of all this, there are persons who rebel against this sooty annoyance and are now clamoring for relief. For my own part I see no reason why the smoke nuisance is not properly as much a matter to be brought under municipal regulation as is now exercised in the matter of traps, sewers and discordant noises.

In presenting this paper I wish to state at the outset that I have no "Patent Smoke Burner" to describe, and no particular device of my own or that of another to bring to your notice, or to recommend for the purpose: all I ask is your indulgence for a few moments to enable me to lay before you some thoughts relative to this subject.

Smoke is a product of incomplete combustion characterized by numerous and minute particles of solid carbon which pass off unconsumed through the furnace into the atmosphere. This can easily be proved by catching a considerable volume of smoke and allowing the particles of carbon to settle by gravity. Once formed and passing beyond the bridge wall of the furnace, it is extremely difficult to do anything with these sooty particles. So that, if we would strike at the root of the matter, we must have not a smoke burning furnace but a smoke preventing furnace.

We may best determine the requirements of such a furnace by knowing the kind and quality of fuel to be burned, and the conditions under which it may be made to yield the greatest amount of heat. I think I can demonstrate to you that the best and most economical furnace is also a smokeless one.

Anthracite and semi-anthracite coals do not ordinarily give off smoke. These are nearly pure carbon; so also, those other fuels which are nearly pure carbon, such as charcoal or coke, burn nearly or quite smokeless. The difficulties in smoke prevention really begin with semi-bituminous, then bituminous, cannel and block coals, and so on through all gradations to lignite, none of which can be successfully burned in an anthracite furnace. Bituminous coal is the most abundant of all fuels in this country. West of the Alleghanies it is, aside from wood, the only fuel to be had, unless we go to the far West, where large deposits of lignite occur.

The bituminous coals of Pennsylvania, Ohio, Indiana and Kentucky are of excellent quality, and almost inexhaustible in quantity.

This fact has led to its almost universal adoption for manufacturing and domestic use. No fault whatever is to be found with the coal as we get it. The fault lies entirely outside of the fuel itself.

Without going into an elementary analysis, we may state approximately that ordinary bituminous coal contains 40 per cent. of hydro-carbon gases and 50 per cent. of carbon.

This, of course, will vary with each locality, but it is sufficiently accurate to suit our present purpose.

When such a piece of coal is thrown upon the fire, the first effect will be to distill the hydro-carbon gases, and it is just here that the smoke is formed—partly by the reduction of the temperature of the furnace, and partly by an insufficiency of oxygen.

The lowering of the temperature of the furnace may be due to the admission of cold air through the charging door, and, to the abstraction of heat from the incandescent bed of fuel by the fresh charge thrown upon it: in either case the effect is the same.

As soon as the charging door is closed, however, the hydro-carbon gases are distilled from the coal, and so rapid is this process of distillation that particles of solid carbon are detached from the larger lumps and

mingle mechanically with the gases in the furnace. More or less oil is expelled from bituminous coal during the early stages of its combustion, from this the lighter hydro-carbons are expelled and ignited first, and in this manner many of these little sooty particles are formed by imperfect or partial combustion. Combustion is said to be perfect when the hydrogen in the fuel is burned to water and the carbon to carbonic acid gas.

In the case of hydrogen, for each pound burned we have approximately 62,000 units of heat. The complete combustion of carbon yields 14,500 units of heat. Olefiant gas yields about 21,400 units of heat. To take an actual example by way of illustration: a sample of Ohio coal yielded by proximate analysis:

	Per cent.
Fixed carbon	60
Volatile matter	31
Water	6
Ash	3

From this we have a right to expect a total of 14,218 units of heat for each pound of coal burned. This expectation is arrived at in this way: .6 of a pound of carbon burned to carbonic acid gas would give us 8,700 units of heat ($14.500 \times .6 = 8,700$). .31 pound of volatile combustible matter in the coal = ($.31 \times 21,400 =$) 6,634 units of heat: adding these together we have a total of 15,334 units of heat.

But some heat is lost by the expulsion of water, and during the process of the liberation of the hydro-carbons, this may be taken at the rate of 3,600 heat units per pound of volatile matter, so that it will be a near enough approximation to say 31 per cent. volatile matter $\times$ 3,600 = 1,116 units of heat to be deducted from the 15,334 units of heat first obtained, which leaves 14,218 units of heat for each pound of coal burned of the above analysis.

During such a combustion no smoke will be given off. The products of combustion will be carbonic acid gas and water. This would yield a temperature, in a perfect furnace, not far from 4,900° Fahr., which we determine in the following manner:

For the complete combustion of 1 pound of carbon we require 2.67 pounds oxygen, making a total product of 3.67 pounds carbonic acid gas. As this oxygen is obtained from the atmospheric air, we would also have in the furnace 8.94 pounds of nitrogen.

The specific heat of carbonic acid is 0.2164, that of nitrogen, 0.244 Then

	Sp. ht.	Heat units.
3.67 pounds carbonic acid	$\times$ .2164	= 0.794
8.94 " nitrogen	$\times$ .244	= 2.181
Total		2.975

units of heat absorbed in raising the temperature of the products of combustion of 1 pound of carbon, 1° Fahr.

The combined weight of these two products is 12.61 pounds.

By dividing the 2.975 heat units by the weight, 12.61 pounds, we have .236 as the mean specific heat.

As already stated, the approximate total heat of the combustion of 1

pound of carbon is 14,500 heat units. Now, if we divide this number of heat units by the 2,975 heat units absorbed, we have 4,870° Fahr. as the highest theoretical temperature attainable by the complete combustion of 1 pound of carbon.

This you understand to be combustion theoretically perfect. Practically, however, the conditions are not so nearly fulfilled, so far as regards temperature, and the complete combustion of carbon to carbonic acid gas.

One source of loss, which may be referred to in connection with the figures just given, is the admission of more air in the furnace than is needed for the necessary supply of oxygen: the 11.61 lbs. of air is, as you know, the minimum theoretical quantity required. Experiments show that 18 pounds is not an unusual quantity of air admitted in the furnace for each pound of carbon burned, the effect of which is to reduce the temperature of the furnace to 3,236° Fahr., or a loss of more than 33 per cent.

If double the quantity of air be admitted, say 24 pounds of air per pound of carbon, the temperature would then approximate 2,450° Fahr., or a loss of 2,420° Fahr. from the theoretical limit, which so nearly approaches 50 per cent. as to say that the temperature is reduced in that amount. If we could burn a pound of coal with say 12 pounds of air, the product to be carbonic acid gas and water, there would then be no such thing as a smoke nuisance—for no smoke would ever issue from such a furnace. When air is admitted to the fire, on an ordinary furnace grate, it passes up from below, and coming in contact with the mass of incandescent fuel gives up its oxygen, which unites with the carbon in the proportion of two atoms of oxygen to one atom of carbon, the result of this union being carbonic acid gas (CO_2). This gas, in passing through the highly heated carbon above it, takes up another atom of carbon, and thus two molecules of carbonic oxide gas are formed (CO).

It is doubtful whether economic combustion has a more destructive enemy than carbonic oxide gas. The figures already given you as the number of heat units for the combustion of 1 pound of carbon to carbonic acid gas are 14,500: if, however, this product be changed in the furnace to carbonic oxide gas, the number of heat units is lowered to about 4,500, or a total loss of 10,000 heat units out of a possible 14,500 for every pound of carbon burned on the grates

This lowering of the temperature of the furnace is exceedingly favorable to the production of smoke. In fact, the furnace becomes simply an apparatus for the destructive distillation of coal. This is the operation going on in thousands of steam boiler and other furnaces at this time.

Whenever and wherever you see smoke pouring out of a chimney, you may safely conclude that the gases escaping therefrom are mainly carbonic oxide gas mingled with nitrogen and the other gases formed by the union of oxygen with the foreign matters in the coal, the whole being thoroughly saturated with particles of solid carbon.

To prevent this great loss, by allowing a combustible gas, such as carbonic oxide, to escape unconsumed, numerous devices have been suggested for supplying the furnaces with heated air above the fire, and thus effecting combustion in the furnace, before the gases have time to escape.

If this can be done in time a great saving in fuel is had.

Carbonic oxide being a combustible gas it requires only a high temperature and a supply of air to ignite, and burn it. By this means the low heating power due to only 4,500 heat units per pound of carbon is raised to 14,500 heat units by the simple admission of air under proper conditions above the fire. During this conversion the sooty particles in the fire yield to the new order of things and unite with the free oxygen in the fire, and are converted into carbonic acid gas. This gas when highly heated has the property of absorbing or dissolving these sooty particles, and so far as this conversion goes, becoming again carbonic oxide gas, which is again reconverted into carbonic acid gas.

I am not sure that this conversion is, by any means, continuous, but something analogous to what has just been read is certainly going on in every properly constructed furnace.

Smoke, then, is to be regarded as a product of imperfect combustion.

The amount of loss by the escape of these sooty particles has been greatly overestimated. The fact is, that the quantity of solid carbon escaping from a smoky chimney is very small indeed. The loss is not in this, but in the fact that a smoky furnace is a sure indication of a low temperature, and the presence of carbonic oxide gas.

There are many devices offered from time to time for "burning" smoke. Many of these have more or less merit, but most of them have little or nothing to entitle them to serious consideration.

The greater number of these devices inject air or steam, or both at the same time, into the ash-pit, over the fire, into or behind the bridge wall, or into any other unappropriated place.

I have talked with many venders of these devices, but I do not now recall a single instance in which the person soliciting patronage could explain in an intelligent manner the operations going on in the combustion chamber of the furnace, what caused the smoke, or how it might be prevented, except, that his apparatus would do it, and it was the only one that would, etc., etc.

There is no doubt that this inefficient representation and ignorant application have had much to do with the general lack of confidence the public have in devices of this kind. The true remedy consists, however, in preventing the smoke, and not in making it and then adding an attachment to burn it.

An objection to some of the steam injectors, in cities especially, is found in the fact that the steam forced in the furnace above the fire becomes simply superheated, abstracting heat from the furnace and then cooling after leaving the chimney; the steam is afterwards condensed, and falls upon the roofs and sidewalks; as there is always more or less soot in contact with the steam, it mingles with the condensed water and makes a very disagreeable moisture in the immediate locality where steam jets are used. In the country this makes little or no difference, but in the city it often becomes quite a nuisance.

If cold air is injected above the fire it should never be in excess of the actual requirements for attaining perfect combustion, and should be admitted as close to the fire and as far from the bridge wall as possible, otherwise a great loss of heat might result by the presence of air in the furnace, performing no useful work and lowering the temperature.

It would be better if cold air were not admitted over the fire at all. and there is a decided economy in borrowing heat from the sides of the furnace or from the bridge wall to heat the air thus admitted, which would be more than paid back by the increased efficiency of the furnace.

The value of hot air is now so generally admitted that little need be said by way of suggestion as to its adoption in all cases wherever practicable. The system of regenerators as now applied, especially to open-hearth furnaces, has shown marked results in favor of high economy, and is a means to an end which deserves far more attention than it has heretofore received.

This is, perhaps, the most economical method now known for heating the air intended for furnace combustion.

The importance of high temperatures in a furnace is well understood, and as a high temperature can only be had through perfect combustion, and as that cannot be had in a faulty and smoky furnace, too much stress cannot be laid upon the advisability and even necessity for reconstruction upon a proper and rational design in order to secure so desirable an end.

Several methods differing from those in common use suggest themselves for the proper combustion of bituminous coal.

One is to feed the fire from below.

It will require but a moment to see that spreading a layer of cold bituminous coal. rich in hydro-carbons, on the top of an incandescent body of carbon is all wrong.

If the coal were fed from below, the air in passing through it would mingle with the hydro-carbon gases and more surely effect a perfect combustion than by the present method of firing.

Another is to burn the coal in a separate chamber wholly surrounded by fire-brick, which shall always be at as high a temperature as is possible, and then carry the products of combustion to any convenient point of application.

Still another plan is to burn the coal incompletely, that is, to carbonic oxide gas, and then burn this gas in the furnace or wherever the greatest heat would be required.

Any one of these methods would yield good results, and be almost, if not entirely, smokeless.

Much may be done in a common boiler furnace, if the furnace that is, the space immediately over the grates be high and roomy enough to effect a perfect mingling of the gases with the atmospheric air.

These few thoughts are thrown out not so much to present my own views on the subject as to draw from others their views in regard to the abatement of the smoke nuisance.

STEEL METHODS AND MANUFACTURE—THE BESSEMER AND BASIC PROCESSES.

By Thomas W. Fitch, Member of the Engineers' Club of St. Louis.

[Address before the Manufacturers' and Miners' Association.]

At the meeting of the association in July the ore resources of the United States, Great Britain, Germany, France, Belgium and Sweden were briefly reviewed. It is now intended to describe in this paper a few

of the steel works of the same countries, and special attention will be paid to the character of the machinery in use, the methods in vogue and the class of labor employed by these selected corporations in the utilization of these resources in the manufacture of Bessemer steel.

There are in this country at present fifteen works operated on the Bessemer system, with thirty-seven converters that are capable of producing in the neighborhood of 2,000,000 tons of Bessemer steel annually, according to the capacity of converters in the United States.

THE EDGAR THOMSON STEEL WORKS.

The steel works of Carnegie Bros. & Co., Limited, will first be placed before you. These works are located on the main line of the Pennsylvania Railroad, 11 miles east of Pittsburgh. The surface area of the works covers about 106 acres, and they enjoy a river frontage on the Monongahela River of 3,300 feet, in addition to the railroad facilities afforded by the Pennsylvania Railroad, which traverses the plant. The water supply, which is abundant, is procured from the river, being carried to a well at which pumps are placed, thence discharged into tanks, from which supply pipes lead to the works. The works are surrounded by a complete system of tracks. Within the past two years important improvements in blast-furnace practice have been successfully inaugurated here. Their C furnace, blown in November 8, 1880, turned out by September 1, 1881, 45,028 tons of Bessemer pig-iron, this production being an average of 1,070 tons per week for six consecutive weeks: later the furnace made 1,276 tons per week, and has now reached a weekly product of 1,500 tons. The dimensions of this furnace are: Height, 79 feet; bosh, 20 feet; hearth, 9 feet; and it has eight tuyeres, three pounds pillar of blast, three Cowper stoves, 60 feet high and 20 feet diameter; temperature of blast, 1,100°.

Furnace C is duplicated in furnace B.

In furnace D—their new furnace—the product runs up to 1,640 tons per week, and 209 250-2240 tons of gray metal have been made in a day's time; recently this furnace reached a production of 1,807 1330-2440 tons per week.

These figures will be all the more interesting when it is remembered that ten years ago 700 tons per week was considered an extraordinary yield of the Lucy furnace; 100 tons per day in a furnace being unheard of. Since then these Pittsburgh furnaces have made 900, 1,100, 1,200, 1,400, 1,500, 1,640, and 1,807 tons per week and nearly 300 tons in one day. It is not difficult to define the reasons for this exceedingly large output. It may be reasonably ascribed to large hearths, inserted tuyeres, good fuel, good stoves, high temperature of blast—say 1,300° to 1,500°—and plenty of air.

The dimensions of furnace D are: Height of stack, 79 feet 4 inches; diameter, just under the gas outlet, 17 feet 6 inches; the bosh is 20 feet in diameter, and tapers gradually to 17 feet 6 inches to a point 7 feet 4 inches below the top, from which it tapers to a diameter of 14 feet at the outlet. There is a gradual incline from the bosh to the top of the crucible of from 20 feet to 11 feet 6 inches; the depth of the crucible is 8 feet 6 inches; centre of cinder notch to top of hearth, 3 feet 6 inches.

Such are the internal dimensions of the furnace which has run out more metal in twenty-four hours than any other furnace in the world.

Furnace D is duplicated in furnace E.

In the converting department are three vessels, 10 tons capacity and made concentric, the nose being central and upright when the vessel is blowing, which permits of the metal being taken in at the rear of the vessel. The employment of three vessels allows of two being always in use and thereby delay at the six cupolas is entirely avoided. The cupolas have 8 feet inside lining, 8 ounces pressure of blast, and each of them has a melting capacity of 300 tons of pig daily. The blast supply is furnished to the converters by the blowing engines at a pressure of 25 pounds to the square inch. All the machinery is manipulated by hydraulic cranes with a pressure of 300 pounds to the square inch.

Much of the capacity of the American works for rapid production is due to their general arrangement. The English vessel centers (excepting only in the latest plant) stand but 3 or 4 feet above the general floor, causing the bottom of the casting pit to fall 8 or 9 feet below it, and in this cramped unventilated space must be performed the largest and hottest manual labor, for there the steel is poured and the red hot ingots and molds handled by the men. The vessel centres, on the contrary, are found 9 feet above the general floor in the American plant, and the pit is only 48 inches in depth—just sufficient in depth for convenience in casting. Therefore all the operations of castings are performed and all the ingots and molds handled by workmen on the general floor of the buillding. The freest of ventilation, easy access and short lifting of molds are thus obtained.

The high vessel, in addition, permits of the removal of the converter bottoms upon the general floor, and by means of the platforms around the vessels at the level of their centre a second story of working rooms is provided : and from this platform the runners are accessible for repairs and the noses for the insertion of scrap.

The rail mills of Carnegie Bros. & Co., Limited, bloom large ingots and roll blooms into single and double length rails, and the same driving and finishing machinery, which is independent, is used. For rails the three sets of rolls next to the engine are utilized, and the other two sets of rolls are employed for rolling billets, etc. While the rail mills are running the rolls may be changed, so that the whole plant can be engaged on an order for merchant sections without delaying the rail plant. That by this method billets and merchant steel are produced with greater cheapness it is not difficult to understand.

Attached to this mill are eleven Siemens heating furnaces and twenty-eight gas producers in five blocks, a sheet-iron cooling tube, leading overhead to the brick gas flue, and two chimneys, each having 6 feet clear diameter, and which are 98 feet high. Hydraulic charging and drawing machinery is also connected with the three ingot furnaces. The 14-inch, three or four-rail ingots are placed in the converting works, while hot, in their respective seats, on a car, ready for charging into the furnaces, and the car is drawn by a locomotive to the front of the heating furnace with an entire Bessemer heat of ingots. This car is so con-

structed that a long peel can be thrust by hand under the ingot, and by passing the chain around the stationary sheave and hooking it upon the end of the peel and then giving water to the hydraulic cylinder, the chain drives the peel and the ingot upon it into the furnace. The ingot is then tipped off by the workmen with the aid of the handles, the peel is withdrawn and slipped under another ingot, which the car conveys to the front of the door into which it is to be charged. In front of each furnace door is a fixed sheave, and the hydraulic cylinders lie under the frames that hold the sheaves. The ingots are withdrawn upon the bogie, which takes them to the blooming train by sliding over them the yoke to which the train is then attached.

The ingots are bloomed in two 3-high trains—one 32 and the other 36 inches—after heating in one of the furnaces. The trains are driven by non-condensing horizontal engines.

The blooming train has feeding rollers driven by an independent engine, and also hydraulic cylinders for raising the feeding tables, turning the ingots over and moving the middle roll, in order to vary the size of the passes as required. A telegraph leads to a 3-ton hammer, and another to the shears. A hydraulic crane places the blooms in bogies, and they are taken to the reheating furnaces before passing to the rail train. The rail train consists of three stands of 3-high 23-inch rolls, to which are coupled billet and merchant rolls as before explained. It is driven by a 46-inch cylinder by 4-feet stroke engines, with a 50-ton fly-wheel. Two sets of carrying rollers, driven by a saw engine (by means of reversing friction clutches), carry the rolled piece from both these sets of rolls to the saw carriage. Either one or both saws may be used, depending upon the kind and length of the product. Carrying rollers, driven by reversing friction clutches from the saw engine, then take the rolled piece to either of the curving machines and hot beds. The place of the usual hot straight engine plate is occupied by long carrying rollers. Lying upon these rollers the rails are pressed by hydraulic fingers against stops, which are so arranged as to give the rail such a curvature that it will be nearly straight when cold. Then, by fingers on an endless chain, it is moved out upon either hot beds. One man and a boy, by means of levers, operate all this moving and curving machinery and also the saws. The rails instead of being twisted and bent into short curves, as they are by hand straightening and curving, are carried by this method without distortion to the hot bed. As a result they cool almost straight, and are not injured by the gags in cold straightening.

The rails are passed from the other ends of the hot bed to the cold straightening presses: thence to the cold beds: thence to the drilling machine, and, if necessary, to the slotting machines; and lastly, out of the mill to the rail yard. The power of these machines is furnished by an 18 × 24-inch engine. All rails not of exact lengths are made so by cold saws run by 11 × 20-inch engines. When double length rails are rolled, the piece is divided in the middle by the hot saw only, and the two fag ends are made the exact length by the cold saw.

The present production of these progressive works per week is estimated at: Blast furnaces, 5,000 tons: converting department, 6,000 tons; rail and billet mills, 5,000 tons.

NORTH CHICAGO ROLLING MILL COMPANY.

Another advanced works of this country is the new plant of the North Chicago Rolling Mill Company, located at South Chicago. The works consist of four blast furnaces, 75 feet high and 21 feet bosh and 9 feet hearth. Coke from the Connellsville district, near Pittsburg, is the fuel used. The different ores are stocked under the overhead railroad tracks, each having an allotted space and thus facilitating efficient mixing. The limestone is stocked in the yard in a similar manner, and the coke supply is housed in a shed 367 feet long and 99 feet wide.

The works are supplied with fire-brick stoves 60 feet, high and 21 feet in diameter, vertical condensing blowing engines 84 inches in diameter, air cylinders 36 inches in diameter, steam 54-inch stroke, thirty to thirty-five strokes per minute, and 72 boilers 36 feet long, 4 feet diameter. The measurements of the building in which the boilers are placed are 248 × 96 feet. These four blast furnaces have a capacity of no less than 5,000 tons of metal per week. The converting house is some 600 feet from the blast furnaces, and consists of three 10-ton converters placed side by side. The blast of 25 pounds to the square inch is supplied by two horizontal engines with steam cylinder 42-inch bore and 60-inch stroke: air cylinder, 66-inch bore and 60-inch stroke.

The pressure pumps for handling the cranes in the steel works are situated in the same building as the blowing engines, and are under the control of the same engineer. They supply 350 pounds water pressure to the square inch. The ladle cranes in the steel works have a backward and forward action, with the usual up and down movement. This converting department is capable of producing 7,000 tons of steel per week, and the general arrangements have been made to effect economical output. The main building is 108 × 113 feet. The spiegel cupola building abuts upon the main converting building, with a passage way in the wall 18 feet by 6 inches, for the convenience of the runners. The house is 66 feet four inches by 55 feet 6 inches, and contains four cupolas of the common form for melting spiegeleisen. The molten metal is taken from the blast furnace up an inclined plane on a narrow gauge track 3 feet above and in line with the vessel in which the metal is to be converted.

The lining department is situated immediately in the rear of the converting house, about 50 feet distant, and is connected by a line of railroad track running from the hoist, situated under the vessels in the steel works, to a turntable in the centre of the lining department. From this turntable a system of short railroad tracks is laid in such form as to accommodate ladles or vessels bottoms, as the case may be. These ladles or bottoms are placed upon a cast iron truck made for this purpose and run exactly under a fire-proof bonnet, which is supplied with gas from six gas producers, placed close by the lining building. The building for the lining department is mainly constructed for the operation of the basic process, but the details for this object are not yet put in, but at the end of the building where the lining and drying for the acid process is done the results are very satisfactory.

Immediately after the ingots are cast they are taken to the rail mill and charged in heating furnaces, where they receive a uniform heat; thence

they are taken to a 3-high train of rolls, which constitute at one and the same time a set of blooming and roughing rolls. The ingot is 12½ inches square, and the bloom leaves the rolls formed for a rail or other shape required. The centre of the last pass in these rolls is in line with the centre of the first pass in the finishing rolls. The 3-high set of rolls is 40 inches in diameter and —— in length, and is driven by a horizontal engine, 42 inches bore, 48 inches stroke, sixty-five revolutions per minute, and a fly wheel of 52 tons. The finishing set of rolls are 2-high and reversing. The formed bloom is carried into these rolls by a line of short feed rollers, driven by a line of shaftings underneath, delivering the piece into the first pass of working rolls, and it is then run through each consecutive groove, being guided into them by an automatic pusher, until the finished bar is produced of three or more lengths as required. These rolls are driven by a pair of reversing compound engines with high pressure cylinder 42 inches bore, 42 inches stroke, low pressure cylinder, 72 inches bore, 42 inches stroke, running 140 revolutions per minute. After the bar is finished it is passed on rollers to a single saw and there cut as desired, being regulated by a revolving stop guided by a workman. The lengths, when cut, are passed upon rollers between two hot beds, where they receive the necessary sweep by a line of fingers, fixed upon a horizontal shaft controlled by a small engine. The rails which are set to sweep are passed by a circular bar operated by an endless wire rope on two or more pulleys, situated at the extreme ends of the hot beds. These beds are located on each side of the sweeping or bending machine, exactly opposite each other, and a rail is placed on each alternately, thus giving the rails ample time for cooling before being drilled. The drilling and slotting is effected by the usual methods.

These works were planned and constructed to simplify the productions of steel by a saving of labor, especially skilled labor, and by a saving of fuel. To accomplish this, heavy and the most approved machinery has been specially adopted to insure a more direct and rapid production of Bessemer steel. The economical advantages of the type of machinery and the methods of working possessed by this mill over the other steel works of the United States, in expert estimation, places the North Chicago Steel Company in the front rank of Bessemer steel practice in the United States.

These are two of the most advanced of the steel works of the United States in their respective though different types of machinery and methods of working.

COST OF LABOR IN THE UNITED STATES AND ELSEWHERE.

The average cost of labor per ton of pig iron in the United States is about $2 and in England about $1. According to the present practice of working in the United States, the cost of labor per ton of steel ingots from the pig is about $2.50, and for reducing ingots to rail the cost of labor is about $5.50, a total of $10 per ton from the ore for labor, against about $3.50 per ton in Europe.

The table below shows the cost of pig iron in the Cleveland district, England, for one half year to March 31, 1879 (all the minerals are given

at about cost price). The company own and raise their own minerals.

	Quantity used. Tons.	Lbs.	Prices at works.	Cost per ton of Iron
Ironstone	3	565	$0.976	$3.20
Coal (calcining)	..	210	.....	11
Coke	1	203	2.56	2.79
Limestone	..	151	89	45
Wages				69
Stoves and repairs				17
Rates and taxes				8
Total				$7.49

The average cost of pig iron, however, in England is about $10 per ton.

The cost of a ton of pig at the furnaces in the Pittsburgh district in the first part of 1879 is stated to be as follows :

	Quantity used. Tons.	Lbs.	Prices at works.	Cost per ton of iron.
Ironstone	1	7	$9.00	$15.30
Coal (calcining)	none		.....	.....
Coke	1	25	2.56 2-3	3.20
Limestone		75	1.15	.71 1-3
Wages				1.25
Stoves and repairs				.50
Taxes				.10
Total				$21.07

The transportation on raw materials is given at $10.27½ in the United States against $2.00 in England.

The prices at Pittsburg for puddling or boiling iron May 30, 1881, were fixed at a minimum of $5.50 per ton, to be advanced when selling price exceeded 2½ cents per pound. Of this sum the puddlers' helpers received about one-third. At Philadelphia July 24, 1880, the minimum price was fixed at $4, and is still at that figure. These represent the wages in the two sections. In England the same class of workmen August 1, 1881—a period of prosperity and good prices—received per ton $1.75.

The following are the approximate rates of wages for men employed in the iron rolling mills in the Western States:

	Per day.		Per day.
Guide mill roller	$12.56	Catcher	3.90
Guide mill heater	7.10	Puddler	4.75
Roughers	3.55	Puddler's helper	2.40
Heater's helper	2.10	Shinglers	8.00
Bar mill rollers	8.00	Shingler's assistant	3.75
Heaters	5.90	Muck roller	10.00
Helper	2.00	Ordinary laborers	1.50
Straightener	1.75	Machinist	2.50 to 3.00
Plate mill roller	12.50	Blacksmith	2.75 to 3.25
Heater	7.95		

The rates of wages in most of the Sheffield trades have been kept up to the standard of five years ago, and in many cases they have been advanced, notwithstanding the great depression in business. But, although the rates have advanced, the amounts actually earned are much diminished, from the fact that there is so much less work to be done. The fact must be considered, however, that men can now earn larger amounts in a given time than in former years on account of the increased facilities, which enable them to work much more rapidly. For instance, the steel for round, half-round, flat and three-square files was formerly made square, and the file forger was obliged to hammer it into the required shape. The same was true of steel for cutlery, including razors, edge tools and many other articles. Now the steel comes to the hand of the

forger from the manufacturer already rolled into shapes suited for the various purposes for which it is designed, thus saving much time and trouble to the forger. The use of machinery also in many operations which were formerly done by hand labor is greatly to the advantage of the workman, since he now receives as much per dozen for the articles he makes as he did formerly, when he could only turn out one-half or two-thirds as many in a day. In such cases machinery has been the friend of the workingman, although he has been in the habit of looking upon it as his enemy.

The following are approximately the rates of wages paid in England :

	Per day.		Per day.
Puddlers	$1.50	Plate rollers	3.00
Helpers	90	Heaters	2.75
Shinglers	2.25	Laborers	90
Assistants	1.50	Machinists	1.25
Rollers	2.00	Blacksmiths	1.50
Assistants	1.25		

The steel works of Wilson, Cammell & Co., Dronfield, England, are of the old English type, excepting that the pits are shallower. There are four 8-ton vessels in two pits, and there is a traveler over the vessels for setting bottoms. The vessel bottoms are set in dry and rammed from the nose of the vessel. The tuyeres are sixteen in number, with thirteen holes of $\frac{3}{8}$ of an inch diameter. The ingots are top-cast and sand-covered: they are slowly and carefully poured, but no funnel is used, and they measure $12\frac{1}{2}$ inches at the bottom and 11 inches at the top, and rarely exceed 1,700 pounds in weight.

"Stickers" are punched out of the molds by means of a hydraulic press. The output for four vessels is about 9,000 tons per month, running $10\frac{1}{2}$ tons per week. Statistics of one month from the books show 46 tons (?), 195 tons per turn—8,970 tons per month, and this output does not keep the rail mill going to full capacity. The Bessemer plant seems to be smoothly run and a good mixture of irons is kept on hand. It is stated that 65,000 tons of ingots have been made without a bad heat.

The products follow in one direction from the pig bank to the rail yard, over a space of 600 × 200 feet, and with the minimum of handling and diversion. The first line of heating furnaces stands 60 feet from the line of the Bessemer pits. From the furnaces the ingots pass in a direct line through the blooming, roughing and finishing trains, at the same heat, to a central hot straightening plate. There are hot and cold beds and finishing tools on either side.

Eight small heating furnaces with two doors each are used. The furnaces are all single and coal fired. They are charged from a bogie by hand and are drawn by means of a hand winch. The ingot is wheeled an average of 80 feet to the train. The bloom runs out of the reversing blooming train upon a car, which carries it by means of a power chain straight ahead 80 feet to the table of the 3-high roughing train (four fixed power rollers). The reversing finishing train stands in line with the roughing, just like ordinary stands of roughing and finishing rolls, but the two trains are quite independent and are driven, of course, by independent engines. The bottom finishing roll stands in line with the mid-

dle roughing roll. Power carriages are on the front side of these trains, by which the piece is transferred laterally from the last roughing to the first finishing pass.

The blooming train is an old clutch reversing train rebuilt for the purpose. The speed of the rolls is moderate, but this allows the piece to enter without chattering, under a large reduction: and as the piece is short and the feeding is rapid the seven passes are made in fair time. The carriage running from the blooming to the roughing tables is driven on a slightly inclined railway by an endless chain movable by means of a clutch attached to the engine which drives the roughing feed rolls. The boy who runs the feed engine of the blooming train works this clutch to bring the empty carriage back. The roughing feed boy brings the bloom up when he wants it. In normal practice the piece does not stop and is not touched with bar or tongs from the last pass of the blooming to the back table of the roughing.

The roughing train is driven direct by a horizontal condensing engine making fifty-two revolutions.

The front fixed table consists of four 18-inch rollers 3 feet apart, driven exactly like the blooming feed rollers by a reversing engine. The floor plate around these rollers is a wrought-iron armor plate, which is nearly on a level with the tops of the rollers. The piece falls out of the upper passes upon this heavy structure instead of being let down by a moving table. The rear table must be a lifting table. It is a flat wrought-iron plate, 24 feet long by 7 feet 1 inch wide, resting on a frame of two 2-inch channel bars, and otherwise stiffened. The table is hinged in the rear on a link, so that it can move forward and back: its inner end is raised by a hydraulic piston, acting through an underneath rock shaft, which also carries a counter-weight. The inner end of the table is connected to the housings by short links in such a way that as the table rises it is moved 16 inches toward the rolls with increasing rapidity, thus throwing the piece into the grooves. There are short rollers fixed in and projecting just above the top of the table and spaced to suit the increasing length of the piece. The workmen stand on the table, and the lifting handle is attached to it. The transfer table, from the roughing to the finishing rolls, looks endwise like a sofa. The piece drops out the last top roughing pass upon the seat, and is pushed by the back up an incline, off the end of which it falls in front of the first finishing pass. The table is 16 feet long, and consists of four rollers in a frame, which is moved by a hydraulic cylinder like the pusher of the Fritz blooming train. The table has to be low to run under the "spools" which carry the piece at the finishing train.

The finishing train is a stand of 2-high reversing 24-inch rolls, 4 feet 9 inches long. The remarks on the constructive features of the roughing train apply equally to this train. The train is coupled direct to the engine which runs at 100 revolutions maximum, and a carrying roller on either side is driven by a belt from the roll necks. The tables consist of a railway on either side upon which are eight traveling rollers or spools 8 feet apart, which roll back and forth 6 feet between stops, as the rail comes upon them. The tracks consist of double-headed rails lying on their sides; the inclination is that of equilibrium; the rollers throw

the piece well out and a slight pressure will start it in. The spools on the front side are $5\frac{1}{2}$ feet long: on the back side they are but 4 feet, so as not to receive the finished rail: this drops on the driven floor rollers, which carry it to the saw.

The ingots are charged and drawn at what we should call a high heat, but not too high for good steel, having plenty of manganese.

There are seven grooves in the blooming rolls, though the first is not used. The screws are not worked. The piece goes twice through the second grove, being quarter turned on the back side, and once through each of the five other grooves, being quarter turned on the front side. It finishes 7×8 inches. The first reduction is 2 inches and the others average 1 inch.

The men are one tongsman on each side, who turns the piece without the aid of hooks, and a boy, who runs both the table engine and the clutch to bring the bloom carriage back. The back tongsman easily keeps the piece going until it gets upon the bloom carriage. The roughing-table boy then works the bloom-carriage clutch. Where the carriage stops the bloom rolls off upon the roughing-table and straight to the train without stopping.

An inspector behind the train watches and sometimes turns over the blooms: badly cracked blooms he pulls off the carriage: these are cold chipped, reheated and swung on to the carriage to go to the roughing train. When blooms come slightly cracked from the blooming train they are sometimes stopped and hot chipped by hand. The roughing rolls take a 7×8 inch piece, and there are six passes, of which the last begins to form the stem. There are two passes on the flat of the flange. The piece is quarter turned once on the back side and twice on the front side. There is a number of spare grooves arranged to rough every pattern of rail made, so that these rolls are not changed until they are too much worn out for use. The 26-inch rolls, at 52 revolutions (after much experimenting) throw the piece just far enough out on the rear table so that the inward movement of the table throws it again into the rolls. Of course the piece sometimes misses entering, and has to be adjusted by bar and tongs. The men at the roughing train are: one barman and one tongsman in front, one barman and one tongsman behind and the table boy. There are no hooks: the turning is skillfully done by the front tongsman while the piece is falling: the turning in the rear at the last pass is aided by the barman, who does little else except work the table lever. After the piece has passed the last time from front to rear of the roughers the transfer table is moved in front of them; it receives the piece and drops it on the spools in front of the first finishing pass. There are five finishing passes all on edge, the piece being turned over in front and rear after each pass. This is because the grooves are all in the bottom roll. Double collars, allowing the gross to be alternately in the top and bottom roll, so as to keep down the fan, would, of course, prevent the necessity of turning over the piece.

There are a tongsman and hooker in front and a tongsman and hooker behind. The piece almost feeds itself, and is not lifted; turning brings it right to enter the next groove.

Rails of 56 to 70 pounds weight receive eighteen passes from an ingot averaging 11¾ in thickness.

The persons employed at the three trains are :

	Men.	Boys
Blooming	2	1
Inspecting	1	0
Roughing	4	1
Finishing	4	0
Foreman	1	0
Total	12	2

This is superior to our best practice, which requires at least four persons at the blooming train, ten at the rail train, and never less than sixteen men to handle and reheat the blooms between the blooming and rail trains; also a foreman and spell hands, say thirty-six men.

The output has been : Flange rail, 58 pounds per yard, rolled in three lengths of 21 feet each ; output averaged 2,064 tons per week of eleven turns, or 345 bars, 63 feet long (1,035 rails), weighing 187 1330-2240 tons per turn. Bullhead rail, 70 pounds per yard, rolled in two 24-foot lengths, 2,761 tons per week of eleven turns, or 251 tons per turn. The waste and ends are stated to be 6½ per cent. on the ingot. The number of second quality rails is stated to be under one per cent. The analysis of borings from three rail ends taken out of the pile at random is as follows :

	No. 1.	No. 2.	No. 3.
Carbon	0·35	0·34	0·34
Phosphorus	0·059	0·053	00.44
Manganese	1·01	1.02	0·97

It is stated that Wilson, Cammel & Co. contracted for all the labor to make a ton of rails from the pig iron piled in the yard to the rails loaded on cars at about $2.

The saw is 70 feet from the rolls. The rail is carried to it on large driven rollers, which project just above the floor. The same piece is carried to the straightening plate by similar rollers. These sets of rollers are driven independently by reversing clutches actuated by a small engine. Great steadiness of running is promoted—first, by placing the saw in the middle of an arbor having pulleys on each end ; second, by sliding the saw frame in and out in horizontal guides having great mass and heavy bearings ; third, by traversing the saw frame from a high speed shaft by means of a worm. If a single saw will cut a bar into five pieces (three rails and two ends) at the rate of 2,000 tons a week, the necessity of two saws to cut a bar into three pieces, in order to keep out of the way of the train in our mills, is not obvious ; more than this, there seems to be a positive advantage in the single saw for double or treble lengths. The last of three rails will inevitably be sawn colder than the first, and if its hot length is determined by the distance apart of the two fixed saws, its cold length will be greater than that of the first. The length to be cut off is regulated by a mechanical stop, operated at will, by a workman. The rails are not lifted from the time they leave the saws until they reach the shipping cars ; the finishing machines stand successively lower ; in fact, the whole plant stands on a long slope, so that stock is brought to the cupola-charging floor and product is removed by means of not very steep sidings from the main line of the Midland Railway. There are four double straightening presses, four drills and two facing

machines. There are eight straighteners working days and three working nights; they get 10 per cent. ($2.44) per day; also the same number of helpers, who get 4.6 ($1.10) per day. The four drills bore and slot 700 rails per turn.

The rail train engine is considered a good type, as far as durability and smooth working is concerned. It is wasteful of steam, as all non compound reversing engines must be, because they cannot get expansion by a short cut-off. The frame of each engine consists of two deep (3½ feet) straight hollow pieces, extending nearly as far as below the center line, and connected at the cylinder by a hollow and deep ring (the whole cast together) against which the cylinder is bolted. The frames of the two engines are clamped by heavy lugs and rings as strongly as if cast together. The rear end of the cylinder slides as it expands and contracts on a bed plate. The journal boxes part nearly at a right angle with the centre line, so as to properly take the thrust.

A matter of interest connected with this plant is the recent report of the directors of Charles Cammel & Co., Limited, Sheffield. That in order to save the heavy cost, $200,000 or $350,000 a year, of railway carriage of materials inward, and of finished manufactures outward, they have resolved to acquire the rail mills of Wilson, Cammell & Co., of Dronfield, and the works of the Derwent Iron Company, at Workington. They will remove their own rail mills and those of the Dronfield firm to Workington, having arrived at the conclusion that in order to make the rail business profitable three conditions must be fulfilled:

1st. The rail mills must be combined with blast furnaces.

2d. These combined works must be situated in close proximity to the sea; and

3d. The blast furnaces must be situated where hematite is found, with ready and cheap access thereto.

These conditions will all be embodied at Workington. To carry out the change $1,750,000 additional capital is proposed to be raised by shares and debentures.

One railway company alone will lose carriage payments worth $600,000 a year.

The proposal has more than a local significance, inasmuch as English manufacturers on the coast are in a strong position for reaching the United States market promptly and cheaply.

THE BARROW HEMATITE IRON AND STEEL WORKS.

These works have sixteen blast furnaces, fourteen of which are built in a row, while the remaining two are half a mile distant. The weekly production of pig iron averages about 6,000 tons, but as it is always calculated that three or four furnaces are out for alterations or repairs, this does not represent the full productive resources of the works. The furnaces were originally (in 1859) 45 feet high, but they were reconstructed to their present height of 62 feet, between 1870 and 1872. The average consumption of fuel is one ton of coke per ton of pig iron produced. The red hematite resmelted is chiefly obtained from the company's own mines in the neighborhood, at Park and at Stank. The former mine, which has been at work for over a quarter of a century, has proved to be the

finest deposit in the district. The latter is the deepest of all the Furness mines. The Furness ore averages about 56 per cent. of metallic iron, and it is valued for its metallic richness, its freedom from phosporous and sulphur, of which ingredients it contains only fractional quantities. In smelting the Furness hematite ore, about 7 cwts. of limestone are used to the ton of iron made. The blast is heated to a temperature ranging between 900° to 1,000° Fah. The furnaces are each filled with six tuyeres. The boshes of the larger furnaces are 21 feet, and of the smaller ones 17½ feet. The blast is heated partly by Cowper's and partly by Gjer's stoves. There are three beam and sixteen grasshopper blast engines. The three beam engines are compound, with blowing cylinders—two of 100 inches and one of 110 inches in diameter—and a stroke of 9 feet. With the exception of the building that contains the latter engines, all the engine houses are built parallel to, and at the back of, the furnaces. The hoists are inclined planes worked by special engines. For the fourteen furnaces there are six inclines, each with a separate pair of engines, the cylinders of which are 16 inches diameter and the stroke 2½ feet. The furnaces are fitted with the bell and hopper apparatus in order to utilize the waste gases, which are sufficient to heat all the boilers and hot-air stoves without any other fuel.

The steel works are parallel to, and about 200 yards distant from, the iron works on the pig-bed side. The Furness Railway runs between the two departments, and the rest of the intervening space is occupied by sidings, filling sheds, and a wrought iron bridge spans the whole of the railway and connects the different departments. The iron works are situated on the shores of the Walney channel, into which the slag is tipped. The quantity of the latter is so enormous that a considerable area of land is annually reclaimed, so much so that several of the furnaces and many of the lines of railway are built on reclaimed land. In the space between the iron and the steel works a block of coke ovens has been built on the Coppee system, now so much adopted on the continent. The group consists of thirty ovens, 30 feet long by 18 inches wide. The steel works are contained in three parallel erections, connected together, from 85 to 105 feet in width and 735 to 875 feet long. Over 3,000 tons of steel by the Bessemer process are made per week. There were formerly eighteen converters, but as this part of the works has undergone reconstruction the number has been reduced to eleven. The accessory machinery embraces two cogging mills, three rail mills and one merchant mill. Rails constitute the chief branch of manufacture, but considerable quantities of tires, fish plates, axles and forgings are also made. The converters are placed in the north end of the buildings. The blowing engines are a short distance off in a separate building. The horizontal engines have 48-inch diameter blowing cylinders, 36-inch diameter steam cylinders and 5-foot stroke. Side by side with these is the usual arrangement of pumps for working the hydraulic cranes. An adjoining house contains a pair of vertical condensing blowing engines with 54-inch diameter blowing cylinders, 40-inch diameter steam cylinders and 5-foot stroke. The pressure of the blast in the converters is from 21 to 25 pounds per square inch, and the average time of blowing is twenty minutes. Formerly the pig iron was remelted. Now the

molten iron is brought direct from the furnaces in ladles on a specially-arranged wagon, and though the molten metal has to travel nearly two miles to get round by a junction, no difficulty is experienced from any appreciable lowering of its temperature. The locomotive brings four charges at once—two in each ladle, and by means of raised sidings enters Nos. 1 and 2 sheds on a level with the converters' tops. The charge is conveyed into the converters by means of cast iron runners. Occasionally a small quantity of Swedish pig iron is added to the charge. After the blow is concluded the usual amount of spiegeleisen is poured in. There are four cupolas for melting the spiegeleisen. The converters vary somewhat in size, but are mostly 16 feet in hight, 8½ feet inside diameter and have a nominal capacity of 10 tons. Each pair is placed in respect to one another at such an angle that if necessary both can pour their contents into the same ladle. The ram to which the ladle is attached is in the center of the pits. It revolves on its own axis and rises by hydraulic pressure. When the ladle is filled the ram is raised and turned around and the steel runs from the bottom of the ladle either into separate ingot molds or by preference into a hollow standard which resembles on a large scale the runner of a casting. Hydrostatic pressure causes the molten metal to flow through horizontal channels made of perforated and specially arranged firebricks, and to rise through the bottom into four, six, or eight molds arranged in two rows. By this means, with one opening of the valve of the ladle most, if not all, of the ingots from that particular blow are cast. In the Bessemer department hydraulic power is solely used for working the cranes, turning the converters, etc. This power is derived from three steam engines each having 18¼-inch diameter cylinder, 3-foot stroke, driving five hydraulic rams varying from 3 to 5 inches diameter.

The steel ingots are taken from the Bessemer department to the Siemens reheating furnaces. The latter are supplied with gas from 72 producers. The method of charging the producers is mechanical. About two tons of coal slack per day is required for each generator.

From the main gas tubes branch tubes lead to the 46 furnaces employed in reheating the ingots and blooms. The cogging-mills are designed to be automatic and to require a minimum of manual labor. The mills are connected to a pair of beam engines, and are driven by a train of wheels arranged for reversing, but detached from each other. The reversing gear consists of a hydraulic cylinder, coupled to a lever, and an ordinary clutch. The rolls in one mill are 30 inches and in the other 36 inches in diameter. The blooms on leaving the cogging mills pass by self-acting rollers to a hammer to be cut into two or three pieces as required. The mill department contains three rail mills, a merchant mill, and a tire mill, and two of the rail mills are 3-high and driven by condensing beam engines, with cylinders 42½ inches diameter and 6-foot stroke. The rail mills are speeded to 1 to 2¼, making 61 revolutions per minute. The rail-mill trains are 26-inch diameter rolls, consisting of three roughing rolls with seven grooves, and three finishing rolls with seven grooves. These grooves are not all used at the same time, five or six grooves in each set of rolls being generally found sufficient. Rails up to 100 feet in length and of very difficult sections are rolled in these mills. Attached

to the roughing rolls in each mill is a hydraulic lift for the purpose of raising the bloom, after passing through the grooves in the bottom rolls to those in the top rolls. The third rail mill is a very powerful reversing mill consisting of a single set of rolls driven by a pair of horizontal engines, which make 100 revolutions per minute, the cylinder being 42 inches diameter, with 4-foot stroke. Self-acting gear carries the rails in each department, and from the saw to the straightening presses, punching presses, drilling and planing machines, in the usual manner. In and about the works there are many miles of railways and numerous buildings. The engines in the various parts of the works, which aggregate 9,000 horse power, require 150 boilers.

THE WEST CUMBERLAND WORKS.

The works of the West Cumberland Iron and Steel Company are situated on the coast of Cumberland, close to the town of Workington. They consist of six blast-furnaces 70 feet high, each making about 500 tons of hematite pig per week. They have all closed hearths and spray tuyeres, and are served by four sets of fire brick and one set of cast-iron stoves. There are two pairs of blowing engines and a single compound beam engine. The larger pairs are condensing beam engines, having 44-inch diameter steam and 96-inch diameter blowing cylinders with 8 foot stroke, running about 20 strokes per minute. The other engines are of the vertical Cleveland type, with steam above the blast cylinders. Most of the iron is taken in a molten state direct to the steel works, a large tunnel having been driven parallel and close up to the furnaces, so that the iron can be tapped at once into the ladles or run down the pig bed, if necessary.

At these works Mr. Snelus applied the system in use there for conveying the molten pig iron from the blast furnace to the converters. In devising this plan he started with the conviction that it was desirable—1st, to construct a ladle and carriage that could be moved about with safety and celerity without being an undue weight: that the ladle should be placed in the most secure position upon its carriage: that it should be easily tipped for pouring out the metal, lifted out with facility when it required to be changed; and that the man in charge of the ladle should be in a good position for turning it over, not only to see what he was doing, but to be out of danger from splashes of metal; 2d, that all turn-tables and lifts should be avoided; 3d, that in order to produce the utmost economy the ladle should be brought as near as possible to the blast furnaces so as not to cool the metal or have more scrap than necessary, and that the metal should be poured directly from the ladle into the converters to avoid the cost and waste of runner making. The carriage and ladle lined ready for use weigh under 10 tons. The converters are arranged according to the usual English plan, facing each other, and a staging has been thrown over the pit between the two converters. The distance between the blast-furnace and converter is about 1,050 feet, and on a comparatively direct line from one point to the other. In order to bring the ladle as close as possible to the furnaces a cutting was made through the pig beds in front of the tap holes, and in order that the pig beds might not be curtailed the cutting is made sufficiently deep to be

covered for casting purposes. In practice the iron is tapped from the furnaces into the ladle—about 3 tons 10 cwt. from each furnace. This is done to insure as far as possible a uniform charge. Five minutes often suffice to tap both furnaces and to get the charge of metal, and in less than five minutes it can be weighed, taken to the converters and poured into the vessel.

The arrangements are such as to produce the minimum amount of scrap and scull and the yield is in consequence increased.

One ladle lasts from 100 to 200 casts before the scull needs to be taken out, and even then it is only the loose coating, and not the brick lining of the ladle that wants renewing.

The practical results obtained in a fortnight's time are stated by Mr. Snelus to have been :

Total metal used, tons	1,023
Ingots made, tons	887
Ladle scull iron, tons	$14\frac{1344}{2240}$
Iron scrap, cleansing of ladle, tons	$1\frac{336}{2240}$
Steel scrap of all kinds, tons	$14\frac{784}{2240}$
Yield of ingots, per cent	$85\frac{8}{10}$
Waste, per cent	$14\frac{2}{10}$
Iron scull scrap, say, per cent	$1\frac{1}{2}$
Steel scrap of all kinds, per cent	$1\frac{1}{2}$
Leaving absolute waste about, per cent	11

A careful system of analyzing the iron from each furnace daily and mixing it, so that the silicon is kept very regular, is followed, and the steel is consequently very uniform in quality. The steel works consist of two Bessemer pits with a pair of $7\frac{1}{2}$ ton vessels in each, blown by a pair of horizontal engines. The steam cylinders are 40 inches diameter and the blowing cylinders 54 inches diameter, stroke 5 feet. An independent condenser has been added to the engines. The pressure of the blast is 25 pounds to the square inch. The hydraulic power is obtained from a double-acting pump, with 8-inch ram and 8-foot stroke. It runs only six or seven strokes per minute to perform all the work. There is no fly-wheel. The power is regulated by an accumulator, the ram being 30 inches in diameter and having a stroke of 24 feet. The working pressure is about 500 pounds per square inch. The product from the converters, amounting to nearly 80,000 tons of ingots in the year, is worked up into rails, billets, and forgings. The ingots are all made heavy enough for four or six rails, and are taken hot to the rail mill. After a slight soaking in Siemens heating furnaces they are cogged in a cogging mill with 34-inch rolls, driven by a pair of reversing engines. Two men do all the work at the rolls, as the ingot is moved in and out by machinery. From the cogging rolls, after being sawn in two, the bloom is taken to the reheating furnaces, and is then rolled off into a double rail by a pair of reversing engines. These are compound and condensing. They have a 3-foot 3-inch stroke and run at a high rate of speed, often up to 90 strokes per minute, during the last passes of the rail. These engines were originally used in Her Majesty's frigate the Liverpool. When this vessel was being broken up the company bought the engines, and they were compounded by adding high pressure cylinders. At the same time the bed plate, connecting rods, etc., were lengthened so as to get a better driving angle. In addition to the rail mill referred to there are also a

23-inch pull-over mill for light sections and a couple of 24-inch plate mills driven by a pair of engines, but reversed by clutch arrangements. The plate mills have made 400 tons of iron plates per week, but are now exclusively engaged on steel plates.

At the iron and steel works there are forty-eight steam boilers, twenty-four of these being of the double-flued Lancashire type with steel flues, five being entirely of steel. The latter have been in use some time and have given every satisfaction. Good water is obtained from a pumping establishment about a mile up the River Derwent, where a couple of horizontal pumping engines are located, each capable of pumping about 2,000 gallons per minute into the reservoir, 120 feet above the river. Altogether the works use about 3,000 gallons of water per minute for boilers, condensers and tuyeres, but half of this is conveyed into an extensive series of cooling channels about one and one-eighth miles long, and is used over again. There are fifty-two engines on the works that work up to about 7,000 indicated horse power.

The iron ore employed at West Cumberland is obtained from the Cleator Moor mines; the coal and coke from the company's collieries about three miles from the works, and the limestone flux from the quarries belonging to the firm at Brigham, about eight miles up the Derwent.

The Rhymey Steel Works are among the latest, as the Barrow were among the earliest, works of the kind erected in the United Kingdom. The plant, having been erected for the purpose of converting old iron works and adapting them to the manufacture of steel, the arrangement was somewhat controlled by the situation of the blast furnaces it was intended to use for the process, and also by the extent of ground available. It was erected for the purpose of making steel by the direct process; that is, by taking the molten iron direct from the blast furnaces and submitting it to the process of conversion on the Bessemer system, instead of running it into pigs and then remelting them in an air furnace or cupola, the favorite method until very recently. More uniform results being obtained by mixing the produce of two or more blast furnaces, this plan is followed here with the means of taking a further supply of iron, when required, from the cupolas (two in number), which are situated alongside the subway leading from the furnaces to the steel works: they are used for remelting the iron made and run into pigs on Sunday, and at such other times as the steel works may not be in operation, care being taken to use such iron in the cupolas as will correct any irregularity in the iron taken from the blast furnaces, and thus secure the desired regularity in quality.

The iron is run from the furnace into a ladle standing on a railway in the subway, and it is drawn by a small locomotive engine up a gradient of 1 in 50. The carriage and ladle now stand on the floor of the converter house, and as they are still below the level of the converters, the ladle full of metal is lifted from the carriage by a 12-ton hydraulic crane and poured direct into the converter, which is then turned up, and the blow commences; this lasts from fifteen to twenty minutes, with a blast pressure of 25 pounds upon the square inch. After the blow the same crane conveys the spiegeleisen direct from the cupola to the converter. An empty casting ladle suspended on the other side of the

crane is now swung round to receive the steel and transfers it to the center casting crane, which is then turned towards the pit, leaving the charging crane and converters clear from obstruction and at liberty for the next blow, which can commence at once while the casting is being proceeded with.

Within the radius of No. 2 ingot crane is placed a monkey for knocking out any ingot which may stick fast in the molds: the top of this monkey is raised by a chain led from a hydraulic crane near the spiegel cupolas, which crane also lifts the spiegeleisen and coke. The stickers are thus dealt with without delay, preventing the unsightly accumulation of stickers, which must take place where appliances for knocking them out are not easily available.

The converters, which are each of 7 tons capacity, are placed side by side on what is known as the American plan: the practice usually adopted in Great Britain and followed in most of the older works being to place them facing each other, and hence the workmen are put to great inconvenience, when engaged in repairing one vessel, by sparks given off from the other.

THE ESTON STEEL WORKS.

In 1877 Messrs Bolckow, Vaughan & Co. opened at Eston in Cleveland, one of the most complete and admirably arranged steel-making establishments in the world. The site of these works, extending over 100 acres of land, adjoins the Darlington section of the Northeastern Railway, and abuts upon the private jetty of the firm, whence the ores are delivered and the finished article shipped without any cost for freightage or other dues. The ore is carried along an over-head railway and is emptied into huge bunkers immediately behind the furnaces. The bunkers are divided for the separate storage of limestone, ironstone and coke, and are built of strong timber with equally strong iron supports. They are fitted underneath with valves, which enables the raw materials to be emptied into the barrows without any manual labor other than that of simply opening and shuting the valves, which are placed underneath the floor of the bunkers at the height of about 5½ feet from the ground. After being filled these barrows are wheeled to the hoists, which are worked by water balances with a break wheel at the top. The water is pumped by ordinary pumping engines into a tank placed at the top of the hoists. Three barrows are carried up at a time, the load being about 1,700 pounds. The water actuating the hoist is obtained from the Eston mines belonging to the firm, and it runs in an open stream down to the steel works, 2½ miles.

There are nineteen blast furnaces immediately surrounding the steel works. Hot-air stoves, each having 2,000 square feet of heating surface, and giving a temperature of 1,100° to the blast, are attached to the furnaces. A 20-ton machine is provided for the purpose of weighing the iron as it comes from the blast furnaces, and the laboratory is placed close by the machine, so that the molten metal can be taken from the ladles and sampled and analyzed without loss of time. It is not the custom, however, to take samples of each cast, as it is believed that the iron will be kept regular otherwise.

The converting house is divided into two departments, the basic and the hematite, each containing four converters in a row, the basic con-

verters being nominally 10 tons capacity each, and the hematite 5 tons. The acid converters are to be changed to basic, and this firm will have eight converters working on the basic process. The vessels are placed at greater distances apart than is common in our American steel plants, with the advantage of greater accessibility and greater room on the platform for charging and other necessary operations. There is one ladle crane to each pair of converters, not top-supported, as in our home works, but balanced by a counter weight. It has the three motions of lifting, moving around a circle, and carrying the ladle out or in from or toward the center, all controllable by hydraulic machinery. Its lift is so high that the ladle can be lifted above the ingot molds when these are standing on the ground level, thus enabling the deep pit to be dispensed with, and greatly facilitating the placing of the ingot molds.

The pig metal used in these converters (both basic and hematite) is all tapped directly from the blast furnaces and brought in ladles to the steel works, hoisted by a hydraulic lift to the railway track on the platform behind the converters, run on this track to the vessel which is ready for it, and tapped through a short runner directly into the vessel, into which the basic additions and a few crop ends or other pieces of scrap have already been placed.

The blow lasts about twenty minutes; the converter is then turned back toward the platform, and a sample taken out and tested by hammering out, cooling and breaking, to determine whether the purification has been complete. When this is done, either with or without a few seconds of extra blowing, the steel is poured into the crane ladle, where it is mixed with the spiegel which has been tapped into two small ladles from one of four cupolas standing together on the platform.

The production does not seem very large in comparison with that of our best works (only 2,500 tons per week for four converters), but no attempt is made to run each converter to its utmost capacity the whole time as in America. Two of the four converters are always idle, but in readiness to be used as soon as the other two are stopped for repairs. The working force of men is only large enough to keep two converters at work, and the men work twelve hours per day instead of eight as in some of the American works.

Throughout the works care is taken to avoid working below the floor line. This arrangement represents a considerable economy over the customary Bessemer process of casting the ingots in pits, seeing that the expense and loss of time incurred in lifting the ingots out of the pits is avoided. Here the technical and commercial success of the basic process is unquestionable. The mechanical difficulties have been successfully surmounted. The works have been in successful operation in this process for nearly two years, and the basic converting department gives less anxiety and trouble than any other department in the works, and proves that the process is in every sense past the experimental stage. After coming from the converters the ingots of steel are heated in Siemens' regenerative furnaces, of which there are a large number covering about two acres, indicating that the works will not be delayed from want of sufficient heating capacity. There are two large 2-high blooming mills for blooming the ingots from 15 inches square down to 7 inches

square. The ingots are handled by hydraulic power, and are rolled without any other manual aid than that supplied by the engineman, who works the cranes and rams. These blooming mills have 40-inch diameter rolls, driven by very large double reversing engines, which are geared down 3 to 1. Each engine has a set of rolls on each side to prevent any stoppage by breakage or any other reason by which one set of rolls may become incapacitated. The ingots, after blooming, are generally not sheared into rail lengths, but are at once taken to the 2-high reversing rail mill, which rolls three or more lengths of rails at once, which are then sawed to lengths by the hot saws.

The rail mill is furnished with 26-inch rolls driven by large reversing compound engines. In reference to the quality of steel made at Eston, a table of fifty-one consecutive blows or heats shows that the variation in carbon by color tests of this whole lot was only between 30 and 40, and in phosphorus only between .04 and .08. A ball of 1,120 pounds falling 15 feet on the finished rail bearings 3 feet 10 inches apart produced deflections varying from $1\frac{7}{8}$ to $3\frac{1}{8}$ inches in a constant length of 24 feet. If this regularity of product obtains through 51 consecutive blows, there can be no doubt it can be duplicated whenever desired; the phosphorus in the finished product is entirely within control of the operator. The elimination of phosphorus to the last traces depends upon the after-blow and the amount of iron which is wasted in order to make sure of such elimination. When rail steel is wanted, to contain not more than .10 P. the after-blow is not carried to such an extent as when boiler plate is wanted, with below .05 P, and in rail steel therefore a variation in P of from .02 to .08 or .10 is quite allowable. Upon this fact, the practical and uniform elimination of phosphorus down to below .05, depends the future of the manufacture of the finer steel in the United States, especially crucible steels, and of Bessemer and open-hearth steels for boiler plates, rivets, stay bolts, and fine sheets for stamping, tin plates, etc. In crucible steel manufacture at present the raw material imported is Swedish wrought iron bars, which are exceedingly costly. Their chemical peculiarity, upon which the whole market value depends, is low phosphorus and low silicon.

A basic Bessemer works in the United States making steel for boiler plate, or such like purpose, containing known quantities of phosphorus, P .01, P .02, P .03, etc., and all necessarily very low in silicon—the scrap of these works thus graded is the very best material in the world for crucible steel, for the open-hearth process, to make into spring and other high-carbon, low-phosphorus, and low silicon steels. So in regard to open-hearth steel boiler plates and other very soft steels. The materials now used are the best extra low phosphorus Bessemer pig, largely imported from England and Sweden for the purpose, Republic or Spanish ores, Chateaugay or other Champlain blooms, or pig iron dephosphorized by some expensive process, such as Krupp's or Bell's washing process, or by ordinary puddling. However obtained, these raw materials are all expensive. If the open-hearth process for the manufacture of soft steel is to live and prosper in competition with the basic Bessemer process, its raw material must be cheapened, and no way is so likely to cheapen it as the introduction of the basic process, and with it basic steel scrap.

As an illustration of profits at Eston we will quote from the last annual report of Bolckow, Vaughan & Co. The report says: "Your directors have pleasure in submitting herewith the company's balance sheet and auditor's report for the year ending December 31, 1881. Having regard to the low prices ruling for pig iron during the second and third quarters, and the unsatisfactory condition of the coal trade over the whole of the past year, the directors feel assured that the results obtained will be considered satisfactory to the shareholders. The amount of profit available for distribution is £305,806 12s. 5d." This is nearly $1,500,000, but this amount "available for distribution" does not represent all the profits of Bolckow, Vaughan & Co. in 1881.

The report adds: "The plant and machinery have been kept in an efficient state, and several important repairs and improvements have been made and charged to revenue account." This means that the value and effectiveness of their works were increased last year, as a basis for future profits, and this was done in addition to setting aside $1,500,000 for distribution.

For the six months ending June 30, 1882, the directors decided on August 25th last to pay an interim dividend at the rate of 7½ per cent. per annum.

The capital of this company, which is already £3,507,360, is about to be increased to £3,857,360 to enable the directors to meet their greatly extending business, and to allow them to proceed with the development of the salt deposits which underlie a considerable extent of their property in Cleveland. They propose issuing the new capital of £350,000 to the extent of £250,000 in ordinary shares of £20 each, and the remaining £100,000 in 5 per cent. preference shares of the value of £20 each. A special meeting of the shareholders is to be held September 24, 1882, to sanction the creation of the additional capital.

LARGE PROFITS NECESSARY.

The measure of the profits which iron and steel manufacturers should in equity receive must, of course, vary according to circumstances; but concerning the general proposition that large profits are necessary it may be asked, how else can large manufacturing enterprises be built up and employment be given to large numbers of people? Large profits are needed to pay for extensions to enterprises originally small, and to provide improvements in methods of manufacture which the progressive spirit of the age and the fierceness of competition are constantly suggesting. In no other way could capital ever have been accumulated to equip and sustain the great manufacturing enterprises of the world. The large capital upon which millions of wheels and spindles, and all other productive machinery, now rest mainly represents profits. Bolckow, Vaughan & Co. was founded in 1841 with a small capital, one of the partners contributing absolutely nothing but his skill and experience as an iron worker, and for many years its operations were conducted on a small scale. In 1850 it entered upon a more prosperous career, and its present extensive works have been created chiefly with the profits of the last thirty years. The great steel works of Alfred Krupp, at Essen, in Germany, the largest in the world, were founded in 1810 by Friedrich

Krupp, the father of the present proprietor, and as late as 1848 they employed only seventy-four workmen. At the present time they employ 17,000 persons. The commercial value of these works and their acessories is greater than that of the works of Bolckow, Vaughan & Co., and yet this immense value may be said to have been created wholly out of the profits derived by one family, in two generations, from an enterprise that was originally very small indeed.

It has frequently happened in the manufacture of iron and steel that in the course of a very few years it has been found necessary to almost entirely change the methods or machinery previously employed, thus entailing great and unexpected expense. In the manufacture of pig iron the introduction of hot blast stoves and powerful blowing engines in late years has required more money than the original cost of the furnaces to which they have been attached. In the manufacture of steel many changes in methods have occurred in recent years, each of which has been exceedingly expensive. Some of these changes, it is true, have been of a radical character, as in the introduction of the Bessemer and open-hearth processes, which may be classed as new industries rather than as modifications of old processes; but even these new methods of producing steel have been modified and improved by experience, while the old crucible process has been almost completely transformed by the introduction, at great expense, of gas furnaces. Years ago, in our own country, a large amount of capital was expended in the erection and equipment of mills for rolling iron rails. Many of these mills have since been abandoned or converted at considerable expense into mills for rolling iron in other forms, while others have been converted at still greater expense into establishments for the production of rails made by the Bessemer or the open-hearth process.

In the report of Bolckow, Vaughan & Co., already mentioned, the necessity for frequent changes of methods and machinery is thus referred to: "The rapid progress of invention connected with the steel and iron trade necessitates the greatest watchfulness on the part of your directors to keep the works and plant in such a state of efficiency as will enable them to obtain the largest production and work with the most economical results." Even in establishments in which new methods and modern machinery have been introduced the annual cost of repairs to and renewals of such machinery as is in use is ordinarily sufficient to absorb no inconsiderable part of the profits. Probably no other business is so destructive to the machinery and other inanimate aids which it employs as the manufacture of iron and steel.

[TO BE CONTINUED.]

DESCRIPTION OF A FLYING FERRY IN WASHINGTON TERRITORY.

BY THOMAS DOANE, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

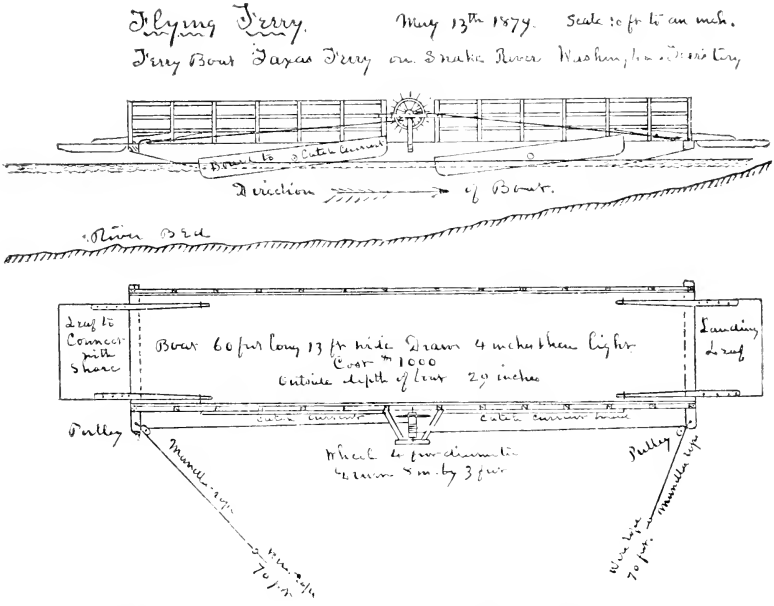
[Read September 21, 1881.]

Herewith are submitted a few drawings illustrating a "Flying Ferry," owned and operated by Mr. Silcott, at the Taxas Ferry, on the Snake River, in Washington Territory.

The scow was 60 feet by 13 feet over all, with landing leaves in addition. The total outside depth 29 inches, with draught of 4 inches when light. The load of a pair of horses with buggy and two passengers displaced about 1 inch more of water. Cost of scow complete, $1,000.

The scow has a strong high railing, in order to carry the wild cattle and horses of the country.

It is provided with two catch current boards, at the up-stream side, each 2 feet wide and 20 feet long. They are hung at their centres, so as to be used in making passages either way, and their lower corners are rounded to prevent their catching at the bottom. These boards are some-



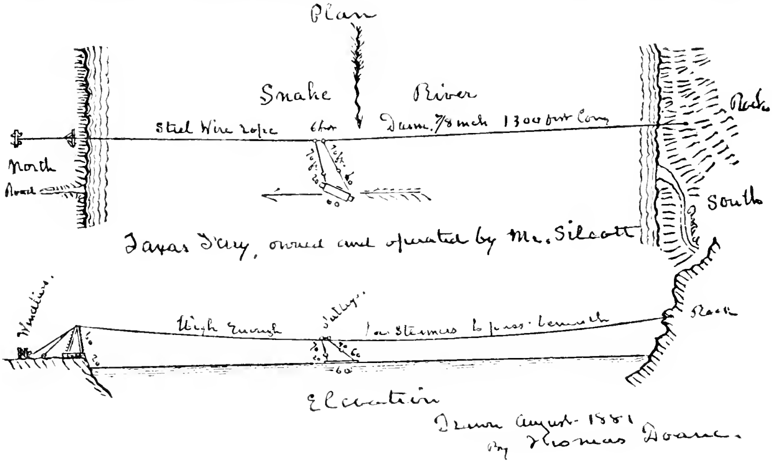
times elevated to the extent of 30 to 40 degrees. As the boat is enabled to make the passage by the force of the river current against its inclined side, the use of these blades is plainly seen to be to secure more of the force of the current, and to take hold of it lower down, where it is more efficient. They are sometimes, perhaps usually, not required, but when the wind blows heavily the passage cannot be made without, and sometimes when the wind is very strong up stream the Flying Ferry will not work.

The machinery of ropes and pulleys must be of the best construction. For so long a crossing as this (1,300 feet), steel wire rope is selected in order to secure great strength with the least possible weight.

The two pulleys running on the wire rope should be of the best possible make of friction pulleys. Two are used, and they are built into or to the two ends of a bar about 6 feet long. This I suppose is done in order to secure at all times a parallelism of the pulley sheaves with the wire rope on which they are to run. From beneath each of these pulleys is

suspended a standing wire rope, about 70 feet long each. To the lower end of those two ropes is attached a common manilla rope, which passes through a pulley at each end of the scow, and reaching the whole length of the scow, makes three or four turns around a wheel at the centre of the boat. This rope is some 140 feet long. It will be perceived that by turning the wheel this rope is let out at one end and taken in correspondingly at the other end. In this manner the inclination of the boat to the current, with reference to the direction or speed of passage, is secured and modified.

There is more or less warfare between the steamboat lines and the ferry companies. It is sometimes difficult and expensive to raise the wire



cables so high as to be above the steamer smoke-stack, especially in freshet times. Sometimes a smoke-stack will go down, and sometimes a rope. The steamers have the right to an open way, and the ferries usually have to pay the damages done. By taking a little pains the steamer can usually pass beneath, even in high water, by hugging one shore or the other, which at that time is entirely safe.

The shears, which have to be erected upon a low shore, are some of them very high. The one at Taxas Ferry has sills of 12 × 16 inches, and three legs of 14 × 14, spreading at the bottom 30 feet. Its height is 64 feet, and it stands 20 feet above the river level.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

SEPTEMBER 20, 1882:—A regular meeting of the Society was called this evening. Present, President Doane and Messrs. Barbour, Folsom, Hodgdon, Lunt, Rice, Sampson and Tinkham. A quorum not being present no business was transacted. President Doane, however, read a short paper describing some conical roofs built by him some years ago in Charlestown, Mass.

S. E. TINKHAM, Secretary.

OCTOBER 18, 1882:—A regular meeting of the Society was held at 7:30 P. M., President Doane in the chair; seventeen members and one visitor present.

The record of the last meeting was read and approved. Mr. Augustus W. Locke was elected a member of the Society and the following were proposed for membership: Mr. F. P. Stearns, by Messrs. Fteley and Brackett; Mr. Wm. P. Granger, by Messrs. Doane and Turner; Mr. R. B. C. Bement, by Messrs. Doane and Bowditch; and Mr. Alfred E. Burton, by Messrs. Vose and Whitaker.

The President announced the appointment of Mr. C. H. Swan, a member of the Committee on the Metric System, in place of Mr. Rice, resigned.

Prof. George L. Vose read a paper on "The Training for Students in Civil Engineering." A general discussion of the paper followed.

[*Adjourned.*] S. E. TINKHAM, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

FEBRUARY 16, 1882:—The 213th regular meeting was called to order by the President. Minutes of last meeting read and approved. Committee on Advertisements for Journal of Association of Engineering Societies reported and was continued. Messrs. D. C. Humphreys and Jas. Dun were ballotted for as members, and declared elected.

A paper on English Engineering in Australia, by Mr. Onward Bates, C. E., was read, and after a brief discussion, the thanks of the Club were presented to Mr. Bates for his able and valuable paper.

[*Adjourned.*]

APRIL 20, 1882:—The 214th regular meeting called to order by the Past-President. Minutes of last meeting read and approved.

Mr. J. B. Johnson was duly elected a member.

Committee on Advertising reported and was continued. Members of Board of Managers Association Engineering Societies reported progress.

Mr. R. E. McMath then read a paper on "Silt Movement, by the Mississippi River, its Volume, Cause and Condition." On motion, a vote of thanks was given to Mr. McMath for his paper.

Mr. C. A. Smith then read by title a paper entitled "A Theorem in Graphical Statics, with Applications," which was ordered printed.

[*Adjourned.*]